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ORIGINAL ARTICLES

SOME OBSERVATIONS ON THE MOSAIC DISEASE OF SUGARCANE IN THE PUNJAB

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I. Introductory

The mosaic disease of sugarcane was first discovered in Java in 1890. Now it is known in almost all the sugarcane-growing countries of the world. The damage caused by this disease, which is in the form of reduction in the yield of cane and juice and deterioration in the quality of cane products has been estimated from six to fifty per cent in different countries.

In India, the disease was first noticed at Pusa (Bihar) in 1921 by Dastur [1923] and was subsequently recorded by McRae 1926 and McRae and Subramaniam [1928] in various other provinces of India. Since then, McRae [1931, 1932

has done a considerable amount of work on this disease under Bihar conditions. McRae [1926] and McRae and Subramaniam [1928] also recorded that many of the newly introduced thin Coimbatore varieties of sugarcane in the Punjab were affected by mosaic. These sugarcanes have been extensively grown in the Punjab for many years now. At the suggestion of Dr. McRae, Imperial Mycologist, Imperial Institute of Agricultural Research, Pusa, a study of the extent of occurrence of the disease and its effect on the yield of cane and juice, etc., was taken in hand in 1927 and carried on up to 1934. Co. 223, which has been largely cultivated in the province, was selected for these observations.

II. Symptoms of mosaic

The affected sugarcane plants show a general pallor of leaves. On a close examination this pallor is found to be due to irregular, light-coloured streaks or patches. These patches vary greatly in shape, but are usually elongated and run parallel to the axis of the leaf. On different varieties of sugarcane the leaf patterns caused by mosaic differ considerably. These patterns on some varieties of sugarcane have been illustrated by McRae and Subramaniam [1928].

The symptoms of the disease can be clearly detected on the first expanded leaves of young shoots, especially if these are growing vigorously. In the Punjab, it has been found that usually the first four or five leaves show the symptoms clearly. In older leaves the characteristic mosaic markings become faint, probably due to regeneration of the normal green tint of the leaf. All the canes in an affected stool may or may not show the symptoms of mosaic.

The symptoms remain prominent from June to October and can be easily observed, but afterwards, as the cane matures and winter frost sets in, the symptoms become rather obscure. The secondary symptoms of mosaic, *i.e.*, dwarfing and cracking of the stem of affected plants, which are common in other sugarcane-growing countries, have not been observed in the Punjab. From other parts of India also, these symptoms have not been reported except very rarely.

III. Incidence and amount of mosaic

The incidence and amount of mosaic has been studied on a number of sugarcane varieties in different localities of the Punjab from 1927 to 1933. The observations were recorded every year during October. The results are given in Table I. The figures given are those of the lowest and the highest percentage of infection, the latter being reached in 1933.

From a study of the figures in Table I, it is clear that the amount of infection on a given variety varies from place to place and that certain varieties are more infected than others. Thus Uba, Treru and Co. 223 were almost totally infected ; S. 48, Co. 205, Co. 309, Co. 270, Co. 262, Co. 349 and Co. 210 had more than 20 per cent infection ; Co. 213, Co. 250, Co. 287, Co. 300, Co. 313, Co. 318, Co. 346 and Katha had more than five per cent and less than twenty per cent infection and other varieties under observation showed less than five per cent or no infection at all.

TABLE I

Incidence of mosaic disease of sugarcane in the Punjab, 1927-33 (Percentage of mosaic affected stools)

Serial No.	Variety	Lyallpur	Montgomery	Multan	Rawalpindi	Gurdaspur	Jullundur	Hansi
1	Co. 205	1	0—9	0	0—2	8—44	0—T	0
2	Co. 210	0—T	..	..	7—25	6—11	..	39—51
3	Co. 213	2	..	..	2—3	T	7—10	6—7
4	Co. 223	18—65	18—100	25—33	7—40	9—51	20—100	0
5	Co. 250	..*	..	..	..	7—11	..	..
6	Co. 251	..	..	..	..	4—5	..	..
7	Co. 262	..	3—5	..	..	1—21	..	..
8	Co. 270	..	..	..	..	7—23	..	..
9	Co. 285	0—2	..	..	T	T—4	3	..
10	Co. 287	12	..	..	..	11	..	..
11	Co. 288	..	..	..	..	3	..	..
12	Co. 290	T	..	..	0	1—2	0	0
13	Co. 300	..	..	..	..	0	9	..
14	Co. 301	..	..	..	..	..	5	..
15	Co. 309	..	..	..	..	0—24	..	..
16	Co. 312	..	..	..	..	..	2	..
17	Co. 313	..	..	..	..	..	9	..
18	Co. 318	..	..	..	..	7	..	..
19	Co. 343	..	..	..	..	..	2	..
20	Co. 346	..	..	..	..	..	10	..
21	Co. 349	..	..	..	..	..	21	..
22	Co. 350	..	..	..	..	..	2	..
23	S. 48	..	..	..	..	55	..	..
24	P. O. J. 2878	..	..	..	..	..	2	..
25	Uba	..	..	..	..	100	..	..
26	Suretha	6	..	..	..	..	1	0
27	Treru	0	..	..	..	100	..	..
28	Katha	0	0	0	..	0—13	0—4	..

* Means either not grown or observations not recorded.
T=Traces.

In addition, observations were also made on many other varieties and the results showed that Co. 203, Co. 242, Co. 244, Co. 253, Co. 260, Co. 272, Co. 275, Co. 276, Co. 294, Ponda and Dhaulu showed only traces of mosaic, and Co. 214, Co. 227, Co. 231, Co. 232, Co. 233, Co. 238, Co. 243, Co. 247, Co. 252, Co. 255, Co. 257, Co. 258, Co. 261, Co. 263, Co. 265, Co. 267, Co. 268, Co. 277, Co. 281, Co. 282, Co. 283, Co. 284, Co. 286, Co. 296, Co. 314, Co. 347, B 1217, B 6308, B 6388, A 2, A 42, Lalri, Kahu and Kansar did not show any mosaic.

IV. THE PROGRESS OF MOSAIC DURING THE GROWING PERIOD OF SUGARCANE

A. Experiments at Lyallpur.—Setts from healthy and mosaic-affected canes were planted in alternate plots and there were four replications of the experiment. The trials were conducted for three years and observations were recorded from June to October every year. The results are embodied in Table II.

TABLE

Showing the development of mosaic during the growing period of sugarcane at Lyallpur

Serial No.	Kind of seed-cane planted	1929 Percentage of mosaic-affected stools in			1930 Percentage of mosaic-affected stools in					1931 Percentage of mosaic-affected stools in					
		June	August	October	Original in the seed-cane	June	July	August	Sept.	October	Original in the seed-cane	June	July	August.	Sept.	October
1	Healthy .	10·9	16·5	93·04	0	1·9	6·0	5·7	5·3	12·1	0	21·3	44·6	52·1	52·0	52·2
2	Mosaic . .	81·8	100·0	100·0	100	69·5	95·2	98·5	99·6	100·0	100	51·1	94·6	100·0	100·0	100·0
3	Healthy .	0·93	1·4	85·7	0	4·6	5·2	6·2	8·3	10·0	0	31·3	37·5	49·5	50·0	50·5
4	Mosaic .	76·4	100·0	100·0	100	71·0	92·9	97·8	99·8	100·0	100	44·5	94·4	99·6	100·0	100·0
5	Healthy .	1·8	2·0	90·0	0	2·6	3·0	6·0	6·1	12·0	0	26·9	40·9	48·3	48·1	49·0
6	Mosaic . .	90·3	100·0	100·0	100	69·3	91·5	97·1	99·4	100·0	100	55·5	93·0	99·5	99·5	99·5
7	Healthy .	2·9	3·6	86·0	0	5·9	7·0	9·2	9·4	14·2	0	15·4	36·7	39·9	41·0	42·5
8	Mosaic . .	...	...	...	100	72·0	94·6	97·1	99·8	100·0	100	59·7	95·1	99·5	99·5	100·0
9	Healthy .	...	...	...	0	2·0	6·5	6·5	7·7	13·4	0	4·4	14·6	16·6	18·0	19·8

It is clear from the figures of the table that the disease goes on increasing from June to October.

B. Experiments at Gurdaspur.—At Gurdaspur, nine varieties of sugarcane were grown on a uniform piece of land. The percentage of mosaic in the seed-canes was recorded and the experiment was carried on for three years. Observations were, as usual, recorded from June to October. The results which are given in Table III again show, as in the case of Lyallpur experiments, that the disease goes on increasing till October.

TABLE III

Showing the development of mosaic during the growing period of sugarcane at Gurdaspur

Serial No.	Name of variety	1929 Percentage of mosaic-affected stools in				1931 Percentage of mosaic-affected stools in				1932 Percentage of mosaic-affected stools in				1933 Percentage of mosaic-affected stools in			
		Original in the seed-cane	June	Aug.	Oct.	Original in the seed-cane	June	Aug.	Oct.	Original in the seed-cane	June	Aug.	Oct.	Original in the seed-cane	June	Aug.	Oct.
1	Co. 290 . .	0·3	0	0·4	0·7	*Nil*	...	0	1·0	*Nil*	0	0	0	1·0	1·0	1·4	1·7
2	Co. 285 . .	T	1·5	3·0	4·3	*Nil*	...	0	1·0	*Nil*	0	0	0	0·3	T	1·0	1·1
3	Co. 281 . .	T	0	0.8	3.3	...	Observations not recorded										
4	Co. 270 . .	19·9	10·0	14·5	23·3	*Nil*	...	5·0	11·0	*Nil*	3·4	5·2	5·8	7·0	3·4	6·3	6·7
5	Co. 262 . .	0·5	1·3	4·7	13·0	Observations not recorded								13·0	2·6	4·5	5·6
6	Co. 223 . .	12·7	58·3	71·9	75·6	*Nil*	...	47·0	51·0	*Nil*	30·2	44·4	55·7	...	21·7	33·0	35·4
7	Katha . .	*Nil*	0·8	4·1	5·7	*Nil*	...	6·0	13·0	*Nil*	1·9	3·0	3·8	Observations not recorded			
8	Co. 205 . .	Observations not recorded				*Nil*	...	14·0	33.0	*Nil*	20·6	37·6	44·4	Observations not recorded			
9	Co. 313 . .	Not grown				Not grown				*Nil*	0·4	0·8	1·1	2·4	4·6	6·5	7·4

It was also noticed in both the above experiments that the canes showed the first symptoms of mosaic about one-and-a-half months after planting.

V. Effect of mosaic on the yield of cane, juice and *gur* (raw sugar)

Experiments to find out the effect of mosaic on the yield of cane, juice and *gur* were carried out both at Lyallpur and Gurdaspur for three consecutive years from 1930 to 1933. The plan of experiments at both the places was similar and the variety under observation was Co. 223. Setts from healthy and mosaic-affected canes were planted in alternate plots and in between every two plots a strip of land 6 feet wide was sown with pigeon-pea (*arhar*) (*Cajanus indicus*) with a view to preventing as far as possible infection by contact and insects from mosaic-affected crop to the healthy one. In 1932-33, Co. 285 cane which has been found to be very resistant to mosaic, and which is taller than pigeon-pea, was grown as a barrier. The yield of stripped cane from every plot was recorded at the time of harvest. The canes from each plot were crushed separately and the juice obtained was weighed. The weight of *gur* (raw sugar) made from juice was also determined for each plot separately. The results along with the statistical analysis of the figures, by Student's method of paired differences, are given in Table IV and Table V. The data show that the differences in the yield of cane, juice and *gur* between crops grown from healthy and mosaic-affected canes are small and not significant for all the three years' trials made at Gurdaspur and at Lyallpur.

TABLE IV

Showing the effect of mosaic on the yield of cane, juice and gur *(raw sugar) of Co. 223 at Lyallpur, 1930-33*

Year	Area of plot in acres	Kind of cane planted	Percentage of mosaic-affected canes in the grown up crop	Actual weight of stripped cane	Difference between the two means	Observed value of *t*	Theoretical value of *t*	Actual weight of juice	Difference between the two means	Observed value of *t*	Theoretical value of *t*	Actual weight of *gur*	Difference between the two means	Observed value of *t*	Theoretical value of *t*	Remarks
				M. S.				M. S.				M. S. Ch.				
1930-31	1/10	Healthy .	12·1	38 5				22 31				3 36 2				
	1/10	Mosaic . .	100·0	29 31				18 16				2 37 8				
	1/10	Healthy .	10·0	28 24				18 39				3 10 6				
	1/10	Mosaic . .	100·0	25 4				16 3				2 28 12				
	1/10	Healthy .	12·0	29 0	+5·5	2·7	3·182	15 21	+2·73	2·7	3·182	2 31 12	+0·55	3·05	3·182	
	1/10	Mosaic . .	100·0	29 17				17 27				3 1 8				
	1/10	Healthy .	14·2	45 0				26 13				4 17 0				
	1/10	Mosaic .	100·0	38 11				21 4				3 27 8				
	1/10	Healthy .	13·4	43 30				23 37				4 13 12				
1931-32	1/20	Healthy .	34·0	37 33				23 27				3 14 8				
	1/20	Mosaic . .	100·0	42 0				27 4				3 24 4				
	1/20	Healthy	35.8	37 37				22 38				3 8 8				
	1/20	Mosaic . .	99·5	33 30				21 24				3 0 4				
	1/20	Healthy .	18·0	38 18	—1·81	0·84	3·182	23 14	—0·43	0·36	3·182	3 16 0	+0·40	0·30	3·182	
	1/20	Mosaic . .	100·0	34 33				20 26				3 1 8				
	1/20	Healthy .	42·0	22 30				19 22				2 39 8				
	1/20	Mosaic . .	99·0	34 18				21 31				3 7 8				
	1/20	Healthy .	24·5	39 17				23 15				3 17 8				

| | | |

TABLE V

Showing the effect of mosaic on the yield of cane, juice and gur *(raw sugar) of Co. 223 at Gurdaspur, 1930-33*

Year	Area of plot in acres	Kind of cane planted	Percentage of mosaic-affected canes in the grown up crop	Actual weight of stripped cane	Difference between the two means	Observed value of t	Theoretical value of t	Actual weight of juice	Difference between the two means	Observed value of t	Theoretical value of t	Actual weight of *gur*	Difference between the two means	Observed value of t	Theoretical value of t	Remarks.
				M. S.				M. S.				M. S. Ch.				
1930-31	1/20	Healthy .	.7	19 28				9 15								
	1/20	Mosaic . .	91	17 19				8 35								
	1/20	Healthy .	14	24 0				12 16								
	1/20	Mosaic . .	95	23 10	*+1·21*	*0·92*	*3·182*	12 18	*+0·33*	*0·41*	*3·182*					*Gur* was not prepared as canes were affected by severe frost
	1/20	Healthy .	17	24 30				13 6								
	1/20	Mosaic . .	88	23 21				11 37								
	1/20	Healthy .	15	24 22				12 17								
	1/20	Mosaic . .	88	26 13				14 1								
1931-32	1/16	Healthy .	34	36 3				21 16				3 1 8				
	1/16	Mosaic . .	98	31 21				18 17				2 30 0				
	1/16	Healthy .	33	27 35				16 32				2 22 8				
	1/16	Mosaic . .	94	27 9	*—0·67*	*1·05*	*4·303*	15 38	*—0·12*	*0·24*	*4·303*	2 17 0	*—0·013*	*0·24*	*4·303*	
	1/16	Healthy .	31	24 21				15 8				2 14 0				
	1/16	Mosaic . .	95	25 26				15 18				2 16 8				
	1/16	Healthy .	30	23 31				13 20				2 9 4				
1932-33	1/16	Healthy .	40	36 37				20 30				3 8 0				
	1/16	Mosaic . .	100	35 20				20 26				3 9 12				
	1/16	Healthy .	38	38 0				23 1				3 27 0				
	1/16	Mosaic . .	100	32 11	*+1·48*	*0·64*	*4·303*	20 3	*+1·03*	*0·91*	*4·303*	3 2 8	*+0·167*	*0·75*	*4·303*	
	1/16	Healthy .	38	36 27				22 26				3 20 0				
	1/16	Mosaic . .	100	37 35				21 36				3 21 4				
	1/16	Healthy .	40	34 0				19 15				3 5 9				

These results lead to the conclusion that in the Punjab mosaic-affected cane crop, having as much as 100 per cent infection, does not bring about any appreciable decline in the yield of cane and other products. Likewise healthy canes with 30 per cent infection gave no significant increase over mosaic canes cent per cent infected.

VI. Effect of mosaic on the quality of juice

An analysis of the samples of juice obtained from healthy and mosaic-affected canes was also made. The samples of cane were taken at random from the plots. The results, along with the statistical analysis of the figures as calculated according to Student's method of paired differences, are given in Tables VI and VII. The data show that the differences, of the percentage of sucrose, glucose and purity coefficient, etc., between the juice obtained from healthy and mosaic-affected canes are not significant. Thus it is safe to say that in the Punjab, mosaic does not cause any significant deterioration in the quality of juice of Co. 223.

VII. Roguing as a method of control

Observations and experimental evidence referred to in the paper have shown that roguing is not quite an effective measure to control mosaic in the susceptible varieties. This measure, however, seems to keep within limit the disease in those varieties which are somewhat resistant. In the case of Co. 223, although roguing had been very carefully done in the experimental plots at the Gurdaspur Farm, yet the percentage of mosaic had remained at about fifty. In Co. 290 and Co. 285, the disease has not gone above two per cent.

TABLE

Showing the effect of mosiac on the quality

Serial No.	Kind of cane	Date of analysis	Percentage of juice	Difference between the two means (Healthy and mosaic)	Observed value of t	Theoretical value of t	Percentage of sucrose	Difference between the two means	Observed value of t	Theoretical value of t	Per cent glucose	Difference between the two means	Observed value of t	Theoretical value of t
1	Healthy . .	16th Jan. 1930.	62·2				10·08				0·167			
2	Mosaic . .	Do.	61·[illegible]				9·49				0·221			
3	Healthy . .	Do.	61·5				9·93				0·206			
4	Mosaic . .	Do.	64·2				10·21				0·283			
5	Healthy . .	Do.	63·7				9·70				0·233			
6	Mosaic . .	Do.	65·0	*—0·445*	*1·7*	*2·571*	9·84	*+0·26*	*0·9*	*2·571*	0·353	*—0·035*	*1·1*	*2·571*
7	Healthy . .	13th Feb. 1930.	65·7				10·88				0·143			
8	Mosaic . .	Do.	65·93				10·61				0·153			
9	Healthy . .	Do.	66·75				10·68				0·180			
10	Mosaic . .	Do.	65·65				9·08				0·133			
11	Healthy . .	Do.	64·58				10·26				0·183			
12	Mosaic . .	Do.	64·64				10·22				0·190			

TABLE

Showing the effect of mosiac on the quality

Serial No.	Kind of cane	Date of analysis	Percentage of juice	Difference between the two means (Healthy and mosaic)	Observed value of t	Theoretical value of t	Percentage of sucrose	Difference between the two means	Observed value of t	Theoretical value of t	Percentage glucose	Difference between the two means	Observed value of t	Theoretical value of t
1	Healthy . .	9th Jan. 1930.	66·5				6·0				3·7			
	Mosaic . .	Do.	66·6				6·0				3·6			
3	Healthy . .	Do.	66·9				5·0				3·6			
4	Mosaic . .	Do.	66·1				5·3				3·6			
5	Healthy . .	14th Jan. 1933.	65·5	*—0·96*	*1·2*	*3·182*	8·3	*+0·065*	*0·15*	*3·182*	0·88	*0·38*	*1·1*	*3·182*
6	Mosaic . .	Do.	65·0				8·1				0·93			
7	Healthy . .	13th Jan. 1934.	62·6				6·80				0·87			
8	Mosaic . .	Do.	65·7				6·79				1·03			

VI

of juice of Co. 223, Lyallpur

Percentage total sugars	Difference between the two means	Observed value of t	Theoretical value of t	Glucose ratio	Difference between the two means	Observed value of t	Theoretical value of t	Percentage of total solids	Difference between the two means	Observed value of t	Theoretical value of t	Purity coefficient	Difference between the two means	Observed value of t	Theoretical value of t
10·247				1·66				11·57				87·1			
9·711				2·33				11·14				85·2			
10·136				2·07				11·07				89·7			
10·493				2·77				11·40				88·9			
9·933				2·40				10·96				88·5			
10·193	+0·279	1·2	2·571	3·59	−0·413	1·3	2·671	10·99	−0.01	0·07	2·571	89·6	+3·1	1·4	2·571
11·023				1·31				12·05				90·30			
10·763				1·44				12·29				86·38			
10·860				1·69				12·24				87·27			
9·213				1·46				12·22				74·27			
10·443				1·79				11·73				87·45			
10·410				1·86				11·64				87·82			

VII

of juice of Co. 223, Gurdaspur

Percentage total sugars	Difference between the two means	Observed value of t	Theoretical value of t	Glucose ratio	Difference between the two means	Observed value of t	Theoretical value of	Percentage of total solids	Difference between the two means	Observed value of t	Theoretical value of t	Purity coefficient	Difference between the two means	Observed value of t / Theoretical value of t	Remarks
9·7				61·5				11·1				44·0			
9·6				60·0				10·9				55·0			
8·6				72·0				9·6				52·1			
8·9				67·9				11·1				52·4			
9·18	−0·3	1·8	3·182	10·6	−5·0	0·7	3·182	10·0	−0·59	2·0	3·182	83·0	+1·5	0·30 / 3·182	Samples unripe
9·03				11·5				9·9				81·8			
7·67				12·8				9·33				72·9			
7·82				15·2				9·60				70·0			

VIII. Summary

1. In the Punjab only primary symptoms of mosaic, *i.e.* mottling of leaves, occur on sugarcane. The secondary symptoms, *i.e.* dwarfing of canes, etc. have not been observed so far.

2. The incidence and amount of mosaic on different varieties of sugarcane grown in the Punjab have been recorded.

3. It has been found that the canes show the first symptoms of mosaic about one and a half months after planting, and then the amount of infection goes on increasing till October.

4. The results of field experiments carried out for three years on the sugarcane variety Co. 223 have shown that there is no significant decrease in the yield of cane, juice or *gur* (raw sugar) on account of mosaic. The quality of juice in Co. 223 also does not deteriorate on account of mosaic.

5. Roguing can keep the disease within limits in those varieties only which are not very susceptible to mosaic.

The authors wish to record their indebtedness to Dr. P. E. Lander, Agricultural Chemist, Agricultural College, Lyallpur, for analysis of various samples of sugarcane juice for us, and to Mr. D. P. Johnston and S. S. Kharak Singh for providing facilities for growing sugarcane at Lyallpur and Gurdaspur, respectively.

REFERENCES

Dastur, J. F. (1923). *Agric. J. Ind.* **18**, 505-509.

McRae, W. (1926). *Agric. J. Ind.* **21**, 198-202.

———— (1931). *Ind. J. Agric. Sci.* **1**, 527-533.

———— (1932). *Ind. J. Agric. Sci.* **2**, 378-384.

McRae, W. and Subramaniam, L. S. (1928). *Agric. J. Ind.* **23**, 239-255.

PHYSICAL PROPERTIES OF SUGARCANE MOSAIC VIRUS

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(With one text-figure)

The resistance of a virus to physical and chemical agents varies greatly. At one end is the highly resistant tobacco mosaic virus and at the other are the viruses of tomato spotted wilt and cucumber mosaic. The present investigation was undertaken to ascertain the position of sugarcane mosaic virus. Such studies involved in every instance infection experiments with the sugarcane plants since by the results of these experiments alone can the effect of any treatment be known.

The artificial transmission of sugarcane mosaic virus has been attended with great difficulties [Matz, 1919; Smyth, 1920 and Lyon, 1921]. Brandes [1919] was successful to a certain extent and Bruner [1922], from his experiments, came to the conclusion, that some unknown factor influenced transmission. Fawcett [1928] could easily transmit the disease to young plants but failed with a little older ones. McRae [1926] and McRae and Subramaniam [1928] obtained cent per cent inoculation, while Sein [1930] improved on the methods previously employed. The latter admitted that the extraction of the virulent juices was a troublesome procedure and since the virus seemed to be readily destroyed or rendered non-infectious, the result would depend on the rapidity and care with which the work was done.

As the results of transmission experiments carried out by different workers have varied from 0 to 100 per cent, it is necessary to give the details of the technique employed in the present work.

It was observed that temperature, humidity and sunshine play an important role in the manifestation of the disease. It was noted during the course of another experiment that dry weather with high temperature and sunshine is favourable for the transmission of the disease provided that the plants are not older than eight to ten weeks. The value of an experiment has been frequently vitiated by an increase in humidity and fall in temperature. Where experiments have been interfered with by a sudden change in weather conditions, such experiments have been repeated. The period of successful artificial transmission of the disease lies roughly between 1st April and 1st June.

Because of these variations the procedure was standardised within practical limits. The material for studies was taken from the Co. 213 variety of sugarcane showing profuse mottling on the leaves. The plants selected were two to four months old. The first four leaves from the top were cut off at their bases and about four inches of each from the tip was cut off and discarded. These portions show no mottling and, being dry, only add to the bulk of the fibre. The leaves were then cut into small pieces with scissors and pounded in a porcelain mortar, distilled water being added gradually with renewed grinding in the quantity of one c.c. per gram of tissue. The juice was extracted through a cheese cloth, pressing with hand, and collected in a clean beaker. The juice extracted was approximately ninety per cent of the water added. All the utensils were carefully washed.

About twenty black Entomological pins No. 10 were mounted (as shown in Fig. 1) in a cork which served as a handle. With a sterile piece of cotton three to four drops of the mosaic juice (after it had received the appropriate treatment) were rubbed on the first open leaf and the spindle, the rest dropped into the hollow produced by the spindle and the open leaf. Inoculation was made by pricking with the sterile pins through juice dropped on the leaf. They were pricked ten to twelve times so that each plant received about 200 pricks. The test plants were also of Co. 213 variety. They were six to eight weeks old growing in large-sized pots.

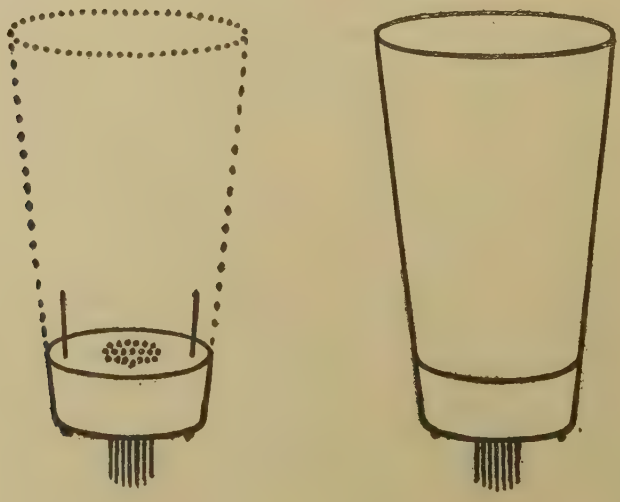

Fig 1. Showing arrangement for pricking leaves.

As purification of the virus cannot be accomplished with sufficient rapidity to enable the inoculation to be completed before the virus has lost its potency from aging, experiments were carried out with the crude virus.

Dilution

One c.c. of the juice was added to 9 c.c. of distilled water and well shaken, obtaining one-in-ten dilution. From this further dilutions were similarly made. These were inoculated to plants within thirty minutes.

Dilutions	Colour of inoculum	Date of inoculation	No. of plants inoculated	Results
1 in 10.	Green	22nd May 1934.	10	Four plants mosaic
1 in 100	Greenish	Do.	10	All healthy
1 in 1,000	Dirty	Do.	10	Do.
1 in 10,000	Colourless	Do.	10	Do.
1 in 100,000	Do.	Do.	10	Do.
1 in 1,000,000	Do.	Do.	10	Do.
Control (undiluted)	Deep green	Do.	10	Do.

Dilution of the virus extract resulted in diminution of the percentage of infection secured and by a dilution of one in hundred the virus entirely lost its potency. Crinkle mosaic of potato also tolerates one in ten dilution, while virus of tobacco mosaic is infectious at a dilution of one in 10,000.

Longevity *in vitro*

The determination of this property is fundamental for experiments on virus properties since it is important to work with the virus in extract in as virulent a form as possible.

Mosaic leaf juice was kept in an incubator at 20°C. from which inoculations were made into ten test plants at intervals shown below. The inoculations were made on 18th May 1934. The number of mosaic-infected plants in each series is given in the following table :—

10 min.	30 min.	1 hr.	2 hrs.	3 hrs.	6 hrs.	12 hrs.	24 hrs.
5	4	4	0	0	0	0	0

The virus, therefore, loses its potency in two hours while that of spotted wilt of tomato does so in six hours against tobacco-mosaic virus known to remain viable for years.

Filtration

The juice was repeatedly poured over a filter funnel till the filtrate was a clear brown liquid. The filtrate was further filtered through L_3 Chamberland filter candle. The residue on the filter paper was thoroughly washed with distilled water, filtered and the residue mixed with distilled water which was then used for inoculation experiments.

Date of inoculation	Plants inoculated with	Inoculated within	No. of plants inoculated	Results
24th May 1934.	Residue left on the filter paper	50 min.	10	Five plants mosaic
Do.	Filter paper filtrate.	40 ,,	10	All healthy
Do.	L_3 filter candle filtrate.	1½ hrs.	10	Do.
Do.	Control	55 min.	10	Five plants mosaic

It was found that no infection was obtained with filter paper filtrate and consequently it could not be expected from the Chamberland filtrate. It is possible that for the successful inoculation two factors are necessary, the virus itself and an accessory, of which neither alone is sufficient to produce the disease and that only one is stopped by filtration.

Reaction to chemicals

In these experiments all concentrations stated as one part of the reagent in 100 or 200, etc., of the solution refer to one gram or one c.c. of actual pure reagent in the indicated volume of the solution. A double-strength concentration of these reagents was first made with distilled water. Ten c.c. of the juice was then added to ten c.c. of this solution, bringing down the concentration to the desired strength. This method was uniformly used.

The chemicals used were Merck's pure reagents.

With stronger concentration of acids and mercuric chloride the leaf tissues were sometimes killed.

Concentrations	Period of contact	Inoculations made on	No. of plants inoculated	Results
		Hydrochloric acid (40 per cent)		
1 part in 750	25 minutes	5th May 1934.	10	All healthy
1 „ 1000	Do.	Do.	10	Do.
1 „ 1250	Do.	Do.	10	Three plants mosaic
1 „ 1500	Do.	Do.	10	Ten plants mosaic
1 „ 2000	Do.	Do.	10	Six plants mosaic
Control	Series A	Do.	10	Six plants mosaic
		Nitric acid (65 per cent HNO_3)		
1 part in 300	25 minutes	5th May 1934.	10	All healthy
1 „ 450	Do.	Do.	10	Do.
1 „ 600	Do.	Do.	10	Do.
1 „ 800	Do.	Do.	10	Do.
1 „ 1000	Do.	Do.	10	Five plants mosaic
Control	Series A	Do.	10	Six plants mosaic
		Mercuric chloride		
1 part in 800	25 minutes	5th May 1934.	10	All healthy
1 „ 1000	Do.	Do.	10	Do.
1 „ 1200	Do.	Do.	10	One plant mosaic
1 „ 1400	Do.	Do.	10	Two plants mosaic
1 „ 1600	Do.	Do.	10	Four plants mosaic
1 „ 2000	Do.	Do.	10	Two plants mosaic
Control	Series A	Do.	10	Six plants mosaic

Concentrations	Period of contact	Inoculations made on	No. of plants inoculated	Results
		Sodium chloride		
1 part in 25 . .	25 minutes	5th May 1934.	10	All healthy
1 „ 50 . .	Do. .	Do. .	10	Two plants mosaic
1 „ 75 . .	Do. .	Do. .	10	Eight plants mosaic
1 „ 100 . .	Do. .	Do. .	10	Six plants mosaic
Control . .	Series A .	Do. .	10	Six plants mosaic
		Copper sulphate ($CuSO_4$. 5 H_2O)		
1 part in 500 .	25 minutes	5th May 1934.	10	All healthy
1 „ 1000 .	Do. .	Do. .	10	Do.
1 „ 1500 .	Do. .	Do. .	10	Do.
1 „ 2000 .	Do. .	Do. .	10	Ten plants mosaic
Control . .	Series A .	Do. .	10	Six plants mosaic
		Hydrogen peroxide (12 volumes)		
1 part in 25 . .	20 minutes	21st May 1934.	10	All healthy
1 „ 50 . .	Do. .	Do. .	10	Four plants mosaic
Control . .	Series B .	Do. .	10	Five plants mosaic
		Formalin (40 per cent formaldehyde)		
1 part in 25 . .	20 minutes	21st May 1934.	10	All healthy
1 „ 50 . .	Do. .	Do. .	10	Do.
Control . .	Series B .	Do. .	10	Five plants mosaic

Concentrations	Period of contact	Inoculations made on	No. of plants inoculated	Results
		Zinc powder		
1 part in 20 . .	20 minutes	21st May 1934.	10	Six plants mosaic
1 ,, 50 . .	Do. .	Do. .	10	Seven plants mosaic
Control . .	Series B .	Do.	10	Five plants mosaic
		Manganese dioxide		
1 part in 20 . .	20 minutes	21st May 1934.	10	Ten plants mosaic
1 ,, 50 . .	Do. .	Do. .	10	Eight plants mosaic
Control . .	Series B .	Do. .	10	Five plants mosaic

Copper sulphate, 1 in 1,500 ; hydrochloric acid, 1 in 1,000 ; mercuric chloride, 1 in 1,000 ; nitric acid, 1 in 800 ; sodium chloride, 1 in 25 ; hydrogen peroxide, 1 in 25 and formalin, 1 in 50 ; inactivated the virus. Zinc powder and manganese dioxide, 1 in 20 did not retard the activity, and the latter may even have enhanced it. These figures compared with those given by Allard [1918] for tobacco-mosaic virus are in a very low concentration indeed and place this virus among the least resistant ones. It was interesting to note that an oxidising agent (hydrogen peroxide, Merck's) had no effect on the virus in 1 to 50 parts, while Johnson [1926] found even a resistant type like tobacco-mosaic virus to be sensitive to the inactivating influence of oxygen.

It was observed from the above results that a larger number of infections was obtained with chemicals in strengths a little more dilute than those to which the virus was just resistant*. This suggests that the virulence may be increased by dilute concentrations of such reagents.

Summary

The technique of transmission experiments with sugarcane-mosaic virus for the study of its physical properties has been standardized.

Like crinkle-mosaic of potato this virus tolerates 1 to 10 dilution. It loses its potency in two hours, thus resembling spotted wilt of tomato which is inactivated in five hours.

* (HCl, 1 in 1,500 ; $CuSO_4$, 1 in 2,000 ; NaCl, 1 in 75 etc.)

Filter paper filtrate is non-infective while the green residue left on the filter paper is infective.

This is one of the most sensitive viruses and shows the least resistance to chemical agents.

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REFERENCES

Allard, H. A. (1918). *J. Agric. Res.* **13**, 619-637.
Brandes, E. W. (1919). *U. S. Dept. Agric. Bull.* **829**.
Bruner, S. C. (1922). *Rev. Agric. Com. & Trab. Cuba* **5**, 11-22.
Fawcett, G. L. (1928). *Rev. Ind. Agric. Tucuman* **18**, 295-299.
Johnson, James (1926). *Science*, N. S. LXIV, 1652.
Lyon, H. L. (1921). *J. Dept. Agric., Porto Rico* **3**, 65-82.
McRae, W. (1926). *Agric. J. Ind.* **21**, 198-202.
McRae, W. and Subramaniam, L. S. (1928). *Ibid.* **23**, 239-255.
Matz, J. (1919). *J. Dept. Agric., Porto Rico* **3**, No. 4, pp. 65-82.
Sein, F. (1930). *J. Dept. Agric., Porto Rico* **14**, No. 2, pp. 49-68.
Smyth, E. G. (1920). *Ann. Rep. Insular Expt. Stn., Porto Rico*, pp. 83-89.

STUDIES IN THE TECHNIQUE OF FIELD EXPERIMENTS

IV. A STUDY OF MARGIN EFFECT IN VARIETY TRIALS WITH COTTON AND WHEAT

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(With one text-figure)

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I. Introduction

The conclusions drawn from previous work on margin effects have recently been summarised in a paper by Christidis [1935], and will not be repeated here. He concludes that experiments should be laid out so that margins can be discarded, as they may introduce bias into the results if included. One point only not mentioned in his summary appears to require comment, and that is the attempt by some workers [Immer, 1932 ; Justesen, 1932 ; and Kalamkar, 1932] to study margin effect in data from uniformity trials. The main components of margin effect which are of interest to the agricultural worker are :—

(1) Influence of inclusion of margins on mean values.

(*a*) General increase due to average reduction in competition at margins, or general decrease due to trampling or other outside interference.

(*b*) Differential effects due to effects of competition between types differing in vigour.

(2) Influence of inclusion of margins on plot variance.

(*a*) Increase in variance due to differential effects of competition between neighbouring plots differing in vigour.

(*b*) Decrease in variance due to greater proximity of the plots to be compared.

(3) Reduction in variance due to increase in plot size when margins are included.

A study of margin effect in uniformity trials can provide information concerning items 2 (*b*) and (3) only, whereas the chief practical importance of the problem lies in determining the magnitude of the effects of competition enumerated under items 1 (*a*), 1 (*b*), and 2 (*a*). It is intended in the present paper to study the relative importance of the different effects of competition.

II. Material

Data are available from four cotton trials carried out in 1933, and one cotton trial and one wheat trial carried out in 1934-35. Of the cotton trials, two were carried out on light soil under irrigation (Ganganagar), one on black soil under irrigation, and two on black soil without irrigation. The wheat trial was also carried out on black soil without irrigation.

Of the 1933 cotton trials, 1 B/33G and 4 B/33G were variety trials conducted at Ganganagar in the Canal Colony in the north of Bikaner State. 1/33 D was a pre-rain sowing *vs.* normal sowing test of American and *desi* cotton in Dhar State in Malwa (a black soil tract) and 2/33 D was a comparison of Institute selections from Malvi cotton with the local *desi* at the same centre. The 1934 cotton trial, V31/34 I, was a trial of seven *desi* varieties carried out at Indore. Details of all are given in the Appendix.

It should be noted here that the area of the experimental plot was approximately 1/100 acre in experiments 4 B/33 G, 2/33 D, and V31/34 I, while in the other two it was much smaller. Another important difference lay in the degree of similarity of growth habits and vigour of varieties or treatments in the same experiment. In the pre-sowing trial at Dhar (Experiment 1/33D) there was a difference of three weeks between the two sowings, so that the earlier-sown plots had extra free space during the period on either side. Between the two varieties used in the experiment Malvi 9 (*desi*) was always taller and probably vegetatively more vigorous than the corresponding American (Indore 25) variety. In Experiment 1 B/33G, out of the seven varieties three were *desi*, three Punjab-Americans and one Egyptian. *Desis* grew tallest, next came the Punjab-Americans while the Egyptian remained stunted. Differences in vigour were probably similar. In experiment 4B/33G, all varieties were *desi*, behaving more alike than in the previous experiment. Mollisoni was most vigorous while Malvi was least. In experiment 2/33D, all except local were selections from the same stock of Malvi

while the local variety also was a Malvi with admixture of American cotton. Differences in growth habit and vigour were therefore expected to be least in this case. The seven varieties included in V31/34 I were all *desi* types, rather similar in vigour.

In both experiments at Ganganagar one row of the same variety on either side and two feet at each end constituted the margin round each experimental plot. In experiment 2/33 D the margin consisted of two rows on either side and three feet at each end of each plot. In experiment 1/33D four rows on either side for Malvi plots, two rows on either side for American plots and three feet at each end of all plots formed the margin. The area removed as margins was the same for all plots in this experiment also, but the spacing between rows was 28 in. in the American plots as against 14 in. in Malvi plots. Spacing between rows was uniform for all varieties in the other three experiments—2 ft. at Ganganagar and 14 in. at Dhar. All cultural operations were identical for the border rows and the experimental plot in each experiment. The distinction between margins and the experimental plot within, was made only for quantitative observations and for harvesting.

The 1933 trials were not laid out with the intention of studying margin effect. The margins of edge plots were not always protected from the stimulus of free space and are therefore not comparable with the margins of inside plots. In analysing data for plots and margins in experiments 4B/33G and 2/33D actual yields of plots having unprotected margins have been ignored owing to their abnormality and probable yields calculated by the missing plot technique [Yates, 1933]. In experiment 1/33 G, the margins of outside plots were protected by other crops of cotton. Experiment 1/33D was laid out as a Latin square, and twelve out of sixteen plots had unprotected margins but they were equally distributed between treatments and varieties, and most of the effect on variance is eliminated in the removal of sums of squares due to rows and columns. Mean increases due to inclusion of margins will, however, be somewhat exaggerated.

The 1933 results demonstrated clearly the existence of important margin effects, and therefore trial V31/34 I was harvested with a view to studying the magnitude and depth of penetration of these effects in more detail. The trial was laid out with 1/100 acre plots with two rows (14 in. apart) on each side and 4 ft. at each end of each plot as margins. Two rows of bulk cotton were sown at each side of each block to protect the margin rows of the first and last plots. Three rows on either side of each plot were harvested row by row. End margins were harvested in three strips, (1) the outer 16 in., (2) the second 16 in., and (3) the third 16 in. Corners were omitted (Fig. 1).

Finally, in order to test the applicability of the conclusions reached to another crop, yield data were collected for margin rows on a wheat variety trial in the *rabi* season of 1934-35. In this experiment eight varieties were tested in 1/100 acre plots in six randomised blocks. Margins consisted of one row on each side

and three feet at each end of each plot. Two rows of bulk were sown at each end of each block to protect the margin rows of the first and last plots. Two rows on either side of each plot were harvested and threshed separately. The effect of end margins was not considered in this experiment.

III. Results

Yields of seed cotton in each experiment were analysed in three ways ; (1) Yields of experimental plots only, margins being discarded. (2) Yields of experimental plots and their surrounding margins taken together—in effect an experiment with larger plots but without margins. (3) Percentage increases in yield per unit area when yields of margin areas are added to those of the experimental plots. Percentage increases were calculated for each plot for the purpose of this analysis. It should be noted that the ' mean percentage increases ' tabulated in Tables I to V for cotton and in Table XI for wheat are not proportional to the differences between acre-yields with, and without margins, since the weightage in the two cases is different.

Mean yields of seed cotton, analysis of variance, mean increases per cent, and significance of differences for each experiment are given in Tables I to V. Under " significance of differences " varieties not differing significantly in yield are included within a bracket.

Table I

Experiment 1 B/33G

Yield of seed cotton (lbs. per acre)

	Cwn. 520	Mollisoni	P 289F	P285F$_2$	0/10/26·1	P289F$_1$	New Ash.	Mean	Standard error	Significant difference
Without margins.	1800	1794	1487	1087	825	262	0	1037	75·7	225
With margins .	2187	2299	1663	1244	1182	357	0	1276	65·9	195
Percentage increase due to inclusion of margins.	21·2	29·6	11·4	15·2	46·1	97·9*	0	31·6	34·4	...

Analysis of variance of plot yields (in chitaks)

Due to	Degrees of freedom	Without margins		With margins		Percentage increase	
		Mean square	*P*	Mean square	*P*	Mean square	*P*
Blocks	3	37·0		105·0		7503·4	
Varieties	6	3286·0	<0·01	12499·0	<0·01	4180·3	Large
Error	18	36·7		72·4		4733·7	
Standard error per cent .	...	7·3		5·2		108·9	

Significance of differences

Without margins.—

Cwn. 520, Mollisoni, P 289F, P285F$_2$, 0/10/26·1, P289F$_1$, New Ash.

With margins.—

Mollisoni, Cwn. 520, P289F, P285F$_2$, 0/10/26·1, P289F$_1$, New Ash.

*This very large increase was almost entirely due to the failure of one plot, and the survival of its margins.

TABLE II

Experiment 4 B/33G

Yield of seed cotton (lbs. per acre)

	N. T. 10	Mollisoni	*Desi*	Roseum	Malvi	Mean	Standard error	Significant difference
Without margins .	1778	1723	1583	1478	1242	1560	49	144
With margins. .	1859	1909	1639	1555	1223	1636	44	131
Percentage increase due to inclusion of margins.	4·6	10·8	3·4	5·4	5·3	5·9	2·4	...

Analysis of variance of plot yields (in chitaks)

Due to	Without margins			With margins			Percentage increase		
	Degrees of freedom	Mean square	*P*	Degrees of freedom	Mean square	*P*	Degrees of freedom	Mean square	*P*
Blocks . .	5	92		5	131		5	24·84	
Varieties . .	4	1735	<0·01	4	6068	<0·01	4	48·98	Large
Error . .	20	92		18 (20-2)	153		18 (20-2)	34·04	
Standard error per cent. . .	3·15			2·66			40·7		

Significant differences

Without margins .—N. T. 10, Mollisoni, *Desi*, Roseum, Malvi.

With margins.— Mollisoni, N. T. 10, *Desi*, Roseum, Malvi.

Table III

Experiment 1/33D

Yield of seed cotton (lbs. per acre)

	Ind. 25 pre-sown	Malvi 9 pre-sown	Ind. 25 normal	Malvi 9 normal	Mean	Standard error	Varieties			Sowings		
							Ind. 25	Malvi 9	Significant difference	Pre-rain	Normal	Significant difference
Without margins .	1271	1491	713	1141	1154	108	992	1316	265	1380	927	265
With margins. .	2048	2431	700	1329	1627	108	1374	1880	263	2239	1014	263
Percentage increase due to inclusion of margins.	61·9	60·9	7·2	16·2	36·6	13·05	34·6	38·7	...	61·4	11·9	31·8

Analysis of variance of plot yields (in tolas *for ' without margins ' and in* chitaks *for ' with margins')*

Due to	Degrees of freedom	Without margins		With margins		Percentage increase	
		Mean square	*P*	Mean square	*P*	Mean square	*P*
Rows	3	35		346		436	
Columns	3	34		711		2716	
Varieties	1	625	<0·05	1521	<0·01	69	large
Sowings	1	1225	<0·01	8930	<0·01	9816	<0·01
Varieties × sowings	1	64	large	90	large	104	large
Error	6	70		69		681	
Standard error per cent.		9·4		6·6		35·7	

Significant differences

Without margins.—Malvi 9 superior to Ind. 25 ; Pre-rain sowing greatly superior to normal sowing.

With margins.—Malvi 9 greatly superior to Ind. 25 ; Pre-rain sowing greatly superior to normal sowing.

Percentage increase.—There is a greater percentage increase in pre-rain sowing than in normal sowing.

TABLE IV

Experiment 2/33D

Yield of seed cotton (lbs. per acre)

	Malvi 8	Malvi 9	Malvi 1	Malvi 3	Malvi 5	Local	Mean	Standard error	Significant difference
Without margins .	456	454	452	446	385	352	424	28	...
With margins. .	471	466	437	433	393	353	426	25	73
Percentage increase due to inclusion of margins.	0·55	3·12	2·37	1·82	1·97	1·93	1·96	2·05	...

Analysis of variance of plot yields (in chitaks.)

Due to	Without margins			With margins			Percentage increase		
	Degrees of freedom	Mean square	*P*	Degrees of freedom	Mean square	*P*	Degrees of freedom	Mean square	
Blocks . .	5	12·4		5	463		5	31·59	
Varieties . .	5	76	>0·05	5	263	<0·05	5	4·22	>0·05
Error . .	25	30·5		21 (25-4)	80		21 (25-4)	25·31	
Standard error per cent.		6·6			5·9			104·7	

Significant differences

Without margins.— Malvi 8, Malvi 9, Malvi 1, Malvi 3, Malvi 5, Local.

With margins.—Malvi 8, Malvi 9, Malvi 1, Malvi 3, Malvi 5, Local.

Table V

Experiment V31/34I

Yield of seed cotton (lbs. per acre)

		G16	G 51	Malvi 9	Malvi 1	Cwn. 520	Local	Roseum	Mean	Standard error	Significant difference
Without margins		520	505	478	477	441	387	384	456	23·9	69
With margins.	Sides .	524	515	481	493	453	384	394	464	21·1	61
	Ends .	513	497	477	470	435	383	378	450	22·3	64
Percentage increase due to inclusion of margins.	Sides .	0·3	2·0	0·3	3·1	2·4	—1·1	1·7	1·2	1·5	...
	Ends .	—1·9	—1·6	+0·1	—1·9	—1·2	—1·3	—3·1	—1·6	1·3	...

Analysis of variance of plot yields (in 10 grams)

Due to	Degrees of freedom	Without margins		With side margins		With end margins		Percentage increase side margins		Percentage increase end margins	
		Mean square	*P*	Mean square	*P*	Mean square	*P*	Mean square	*P*	Mean square	*P*
Blocks . . .	5	1368		4142		1237		23·6		35·8	
Varieties . .	6	3610	< 0·01	8101	< 0·01	5769	< 0·01	12·8	large	5·6	large
Error . . .	30	702		967		959		12·8		9·7	
Standard error per cent.		5·2		4·5		4·9		118·4		81·3	

Significance of differences

Without margins.—G16, G51, Malvi 9, Malvi 1, Cwn. 520, Local, Roseum.

With side margins.—G16, G51, Malvi 1, Malvi 9, Cwn. 520, Roseum, Local

With end margins.—G16, G51, Malvi 9, Malvi 1, Cwn. 520, Local, Roseum.

That margin rows usually yield more per unit area than inside rows is well known [McClelland, 1929; 1934; Hollowell and Heusinkveld, 1933; Deming and Brewbaker, 1934; Coombs, 1934]. This is borne out in the experiments examined, every variety or treatment in all experiments except V31/34I registering an increase in acre-yield when margins are added to the experimental plots. In experiment V31/34 I also, the inclusion of side margins caused a small increase in acre-yield in all varieties save one. The inclusion of end margins, however, caused a small decrease in yield in all varieties save one. This influence of margins in causing an increase in acre-yield has persisted even after allowance has been made by the missing plot technique for the disproportionately large increases in yield of margins of unprotected outside plots.

In Table VI are given the percentage increases in yield per unit area resulting from the inclusion of margins of unprotected outside plots, and of margins of inside plots of the same varieties.

TABLE VI

Percentage increase in yield per unit area when margins are included

Experiment	Variety	Unprotected plots	Protected plots
4B/33G	Malvi	18·1	4·7
2/33D	Malvi 1	37·8	1·9
	Malvi 3	22·9	1·4
	Malvi 8	27·5	1·2
	Local	31·5	1·6

An increase in yield per unit area of from 18·1 to 37·8 per cent has resulted from the inclusion of unprotected outside margins, whereas only 1·2 to 4·7 per cent increase resulted from the inclusion of margins of inside plots. Clearly the increased yield of margins of protected plots demonstrated in Tables I to V is very small compared with that of margins of plots without a cotton crop on one side, and though, as will be shown later, it may in certain cases be advantageous to dispense with plot margins, this can only be done when outside plots are adequately protected by guard rows.

The observation, that in all cases margin rows gave higher yields than inner rows of the same plots, shows that competition must be less between plants of different varieties than between plants of the same variety. A comparison of data from experiments including widely different types or treatments with that from

experiments including types of similar habit is given in Table VII and shows that where differences were greater, competition was less and increases in marginal yields greater.

TABLE VII

Percentage increase in yield per acre due to inclusion of margins

Experiment	Type of comparison	Mean increase	Range of increase
1B/33G	*Desi vs.* American varieties .	20·6	0 to + 46·1*
1/33D	*Desi vs.* American, and pre-sowing *vs.* rain-sowing.	36·6	+ 7·2 to + 61·9
4B/33G	*Desi* varieties . . .	5·9	+ 3·4 to + 10·8
2/33D	Malvi (*desi*) selections .	2·0	+ 0·5 to + 3·1
1/34I	*Desi* varieties — side margins .	1·2	— 1·1 to + 3·1
	Desi varieties — end margins .	—1·6	— 3·1 to + 0·1

*P289F_1 gave an increase of 97·9 per cent, but this was almost entirely due to the failure of a single plot, and has, therefore, been omitted from the calculation of the mean in this Table.

In the two experiments in which both *desi* and American types were included, the mean increase in acre-yield resulting from inclusion of margins was 20 and 35 per cent and varied for individual varieties from 0 to 60 per cent. Where only *desi* varieties were included in an experiment, the mean increase due to inclusion of margins was not more than six per cent, and varied in individual varieties from —1 to + 11 per cent.

Examination of the increases in different varieties (Tables I-V) shows that in general the more vigorous varieties gave the greater increases on inclusion of margins. Examples are 0/10/26·1 (vegetatively very vigorous, though low-yielding) and Mollisoni in 1 B/33G, Mollisoni in 4 B/33G, and pre-rain sown plots in 1/33D. The standard error of increases was, however, very large in all cases, and none of the differences in increase except that due to sowing date in 1/33D were significant.

The influence of inclusion of margins upon the standard error of an experiment is the resultant of the effects of two opposing forces ; (1) the greater variability of margins due to differential effects of different neighbours on the plots of each variety, and (2) the reduction in variability associated with increased plot size [Hutchinson and Panse, 1935]. The resultant effect on the standard errors of the experiments under discussion is shown in Table VIII, where plot sizes and their standard errors per cent are given for plots alone, and plots *plus* margins.

TABLE VIII

Plot sizes and standard errors per cent for plots, and plots plus margins

Experiment	Margins excluded		Margins included		
	Plot size (acre)	Standard error per cent	Plot size (acre)	Percentage increase in plot size	Standard error per cent
1/33D	0·001	9·4	0·005	400·0	6·6
1B/33G	0·005	7·3	0·008	48·1	5·2
4B/33G	0·01	3·2	0·015	45·6	2·7
2/33D	0·01	6·6	0·018	83·0	5·9
V31/34I	0·01	5·2	0·013	33·3	4·5 (including side margins)
			0·012	25·8	4·9 (including end margins)

The net effect in all cases is a considerable reduction in standard error per cent. As would be expected, the reduction is greater in experiments 1/33D and 1B/33G, as the advantage of increasing the size of the plot is greater when the plots are small.

In the calculation of data for Table VIII, the missing plot technique was used to adjust the yields of plots in experiments 4B/33G and 2/33D which had unprotected margins. A comparison of standard errors per cent of plots *plus* margins using actual and adjusted yields gave the following figures :—

Experiment	Standard error per cent of yield	
	Actual	Adjusted
4B/33G	3·4	2·7
2/33D	8·4	5·9

These figures emphasise the conclusion drawn from the corresponding figures for mean values that though it may sometimes be advantageous to provide no margins, this can never be done unless adequate guard rows are provided to protect outside plots.

In Tables I to V are given the order of yield of varieties and treatments, and the significance of yield differences, for plots excluding margins and plots *plus* margins separately. Only four changes in order occurred when margins were included, and all changes were due to small differences between varieties not differing significantly in yield. There were, however, a number of changes in significance where the order remained the same. In experiment 1B/33G, $P285F_2$ gave a significantly higher yield than 0/10/26·1 when plots were considered without margins. Owing to the high relative yield of margins of 0/10/26·1, when plots *plus* margins were considered, it was not significantly inferior to $P285F_2$. In experiment 4B/33G, the difference between Mollisoni and *desi* fell just short of significance when plots alone were considered, but was double the value required for significance when plots *plus* margins were considered. In experiment 1/33D the significance of both varietal and sowing date differences was increased by the inclusion of margins, but in this case the greater differentiation between sowing dates is misleading, since margins of early-sown plots had a significantly greater advantage than those of normal-sown plots. In experiment 2/33D, when margins were excluded, the differences between varieties could not be regarded as significant. The inclusion of margins, however, caused a slight increase in acre-yield and a decrease in standard error, so that the differences in yield between the first three varieties and the last are now distinctly significant. In experiment V31/34I the inclusion of side margins gave a slightly better differentiation between varieties. The inclusion of end margins did not alter the significance of differences.

On the whole, therefore, the inclusion of margins has increased the efficiency of the experiments in practically all cases by reducing the standard error per cent. This increase in efficiency has been gained at the expense of a slight loss in the accuracy of the mean values, but only in the case of the pre-sowing experiment (1/33D) has this loss of accuracy acted differentially between treatments and given a misleading result.

In the cotton trial V31/34I side margins and end margins were studied in detail. In Fig. 1 is given a diagram of a single plot to show the method of harvesting.

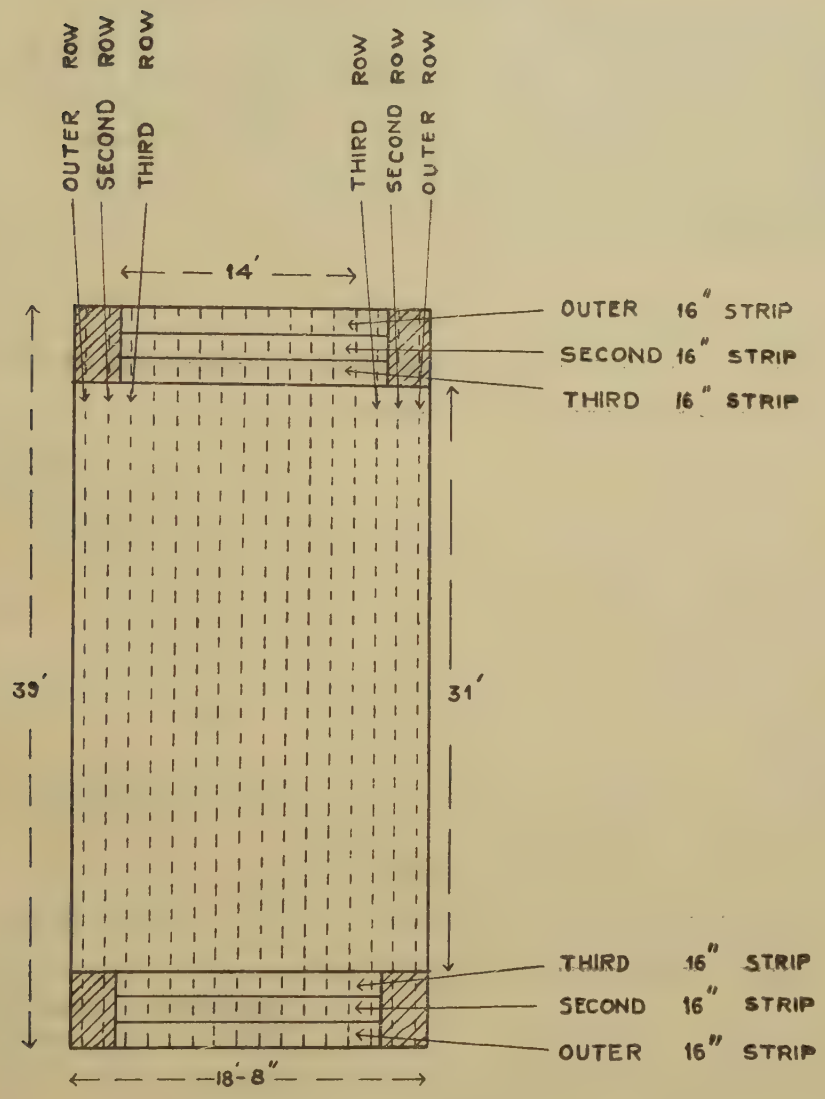

Fig. 1. A single plot in experiment V31/341showing arrangement for harvesting marginal areas..

For the study of the effect of side margins, the produce of the outer rows, the second rows, and the third rows on either side of each plot was harvested separately, making three sets of data from progressively increasing distances from the edge of the plot. Similarly for the study of end-of-row margins, three strips 16 in. wide were marked off at each end of each plot, and the produce of the outer, second and third strips harvested separately to provide three sets of data from different distances from the ends of the plots. Means and standard errors per cent are given in Tables IX and X.

TABLE IX

Mean yields and variances of plots and side margins in cotton trial V31/34I

	Mean yield (lbs. per acre)	Standard error per cent
Plot with margins excluded	456	5·2
Plot with side margins included . . .	464	4·5
3rd and 14th rows	449	7·7
2nd and 15th rows	452	8·1
Outer rows	509	9·9

TABLE X

Mean yields and variances of plots and end margins in cotton trial V31/34I

	Mean yield (lbs. per acre)	Standard error per cent
Plot with margins excluded	456	5·2
Plot with end margins included . . .	450	4·9
Inner 16 in. strips	409	8·6
Middle 16 in. strips	430	10·3
Outer 16 in. strips	396	9·2

Considering side margins, both sets of inner rows gave approximately the same yield per unit area as the central plot, while the outer rows gave slightly more. The standard error per cent was very similar in the two inner sets, and was considerably and significantly greater in the outer rows. Considering end margins, the yield per unit area was rather less in all margin strips than in the central plot and did not differ much from strip to strip. Standard error per cent was much the same in all three margin strips. The whole of the margin effect, therefore, appears to be located in the outermost side rows. There appears to have been no margin effect in end of rows in spite of the fact that they were not protected by guard-rows.

In Tables XI and XII are given data for the wheat trial 2V12/34I comparable to that given for cotton trials in previous tables.

TABLE XI

Experiment 2V12/34I (wheat). Yield of grain (in lbs. per acre)

	P. 8A	Bansi 224	P. 9D	Local	Bansi Pili 808	C. P. 115	Pusa 114	Cross 591	Mean	Standard error	Significant difference
Without margins . . .	766	751	749	689	670	660	638	630	697	29·1	82
With margins . . .	758	774	746	708	673	685	635	623	700	27·2	77
Per cent increase due to inclusion of margins	0·2	4·6	0·8	4·0	1·7	1·9	0·6	0·1	1·7	1·0	2·9

Analysis of variance of plot-yields

Due to	Degrees of freedom	Without margins		With margins		Per cent increase	
		Mean square	*P*	Mean square	*P*	Mean square	*P*
Blocks	5	1443		1925		13·5	
Varieties	7	415	<0·01	655	<0·01	17·8	<0·05
Error	35	126		153		6·4	
Standard error per cent .		4·2		3·9		60·1	

Significance of differences

Without margins.— P. 8A, Bansi 224, P. 9D, Local, Bansi Pili 808, C. P. 115, Pusa 114, Cross 591.

With margins.— Bansi 224, P. 8A, P. 9D, Local, C. P. 115, Bansi Pili 808, Pusa 114, Cross 591.

TABLE XII

Mean yields and variances of plots and side margins in wheat trial 2V12/34I

	Mean yield (lbs. per acre)	Standard error per cent
Plots with margins excluded	697	4·2
Plots with margins included	700	3·9
2nd and 13th rows	693	4·8
Outer rows	756	5·9

The margin effects observed are in all respects similar to those observed in cotton trials. Slight increases in mean yields were observed in all varieties when margins were included. These increases were greatest in Bansi 224, which was considerably earlier than any other variety in the experiment except Bansi Pili 808, and had a considerable advantage in height over its neighbours from the early stages until ripening, and in local which was tall and tillered vigorously. These two gave a significantly greater increase on inclusion of margins than any other variety except C. P. 115 and Bansi Pili 808. The Punjab varieties (8A, 9D and Cross 591) were considerably slower in development in the early stages than the other varieties, and this appears to be responsible for the very small increases in their margin rows.

The standard error per cent is slightly reduced by the inclusion of margins, but the advantage is less than in most of the cotton trials. This is partly accounted for by the fact that the inclusion of margins only increased the plot size by 17 per cent.

The inclusion of margins caused two changes in the order of yield, P. 8A and Bansi 224, and Bansi Pili 808 and C. P. 115 changing places. These changes, however, hardly affected the significance of differences. The reduction in standard error when margins are included has somewhat improved the differentiation between varieties.

In Table XII are given mean yields per acre and standard error per cent for outer rows of each plot, and the second and thirteenth rows of each plot. As in the cotton trial, only the outermost rows exhibited margin effect in increased mean yield and increased standard error per cent, the difference in standard error per cent approaching the customary $P = 0{\cdot}05$ point for significance.

IV. DISCUSSION

It has been shown that the importance of margin effect depends primarily upon the magnitude of the differences between the varieties or treatments included in the experiment. Where differences are large, large disturbances in mean values

may be expected if adequate margins are not provided, and misleading conclusions may be drawn. Where differences are small, disturbances in mean values are not likely to be important, and the efficiency of the experiment will probably be improved by using the area otherwise discarded as margins to increase the plot size. If experiments can be laid out without margins, the management of out-station experiments where skilled supervision is not available will be greatly simplified.

Where variety differences are large, and the provision of margins is essential, one row on either side of each plot should be adequate. Where end margins were tudied separately no evidence of margin effect was obtained and margins actually elded slightly less than central plots. This was probably due to irregularities in seed rate at the ends of plots and to extra trampling at the time of sowing. A safe precaution would be to leave three to four feet at each end of each plot to allow for possible mixing of seed or irregularity in sowing. Only one experiment (1/33D) was studied in which an agronomic treatment was included, and in this case large plot margins were provided, and the depth of penetration of margin ffect was not studied. It is probable, however, that with the large differences between treatments often employed in agronomic trials, larger margins may be necessary than in variety trials.

Margin effect varies considerably not only from variety to variety, but also from plot to plot of the same variety in the same experiment. This is due to the fact that different plots of a variety have different neighbours, and the effects of competition on plot margins depend upon the relative vigour of the variety and its neighbour. Where a markedly inferior variety is in competition with a superior variety, the normal increase in yield of margins over central plots may be reversed in plots of the inferior variety. Almost always in the experiments under discussion, however, margins of all varieties have yielded more than their central plots, and this indicates that competition between varieties is not usually so severe as competition between plants of the same variety.

The range of conditions under which the cotton trials were carried out, and the confirmation of the results obtained from them by the data from the wheat trial justify the belief that the relative importance of different components of margin effect are very similar under most conditions likely to be met with in practice.

V. Summary

Studies are reported on the extent and importance of margin effect in variety trials on cotton and wheat.

The cotton trials were grown under a range of different conditions including irrigated and dry, and black cotton soil and sandy soil.

It is shown that the magnitude of the effect of margins on means depends primarily upon the extent of the differences between the varieties included in the trial.

Where differences between varieties were great, margin effect was large, and failure to allow adequate plot margins would have resulted in the drawing of erroneous conclusions. Where differences between varieties were small, margin effect was small, and the inclusion in the plots of areas, otherwise to be discarded as margins, caused a reduction in error which materially improved the efficiency of the experiment.

It is concluded that where markedly different varieties are to be compared, one row on either side of each plot will be adequate for side margins. For end margins three to four feet should be provided at each end of each plot to allow for the effects of trampling, irregularities in sowing and possible mixing of seed. Where varieties to be tested are similar in habit, it is actually advantageous to dispense with margins especially where other considerations make it desirable,—*e.g.*, where difficulties of control in out-stations make simplicity essential—but in such cases it is most important to surround the experiment with guard rows of bulk crop to protect the outside plots. With the wide differences in treatment common in agronomic experiments, wider margins are probably necessary.

The data show that in almost all varieties studied, competition between varieties was less than between plants of the same variety. Where margins are dispensed with, therefore, yields will be somewhat over-estimated.

VI. Acknowledgments

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REFERENCES

Christidis, B. G. (1935). *J. Agric. Sci.* **25**, 231.
Coombs, A. V. (1934). *Emp. J. Expt. Agric.* **2**, 315.
Deming, G. W., and Brewbaker, H. E. (1934). *J. Amer. Soc. Agron.* **26**, 615.
Hollowell, E. A., and Heusinkveld, D. (1933). *J. Amer. Soc. Agron.* **25**, 779.
Hutchinson, J. B., and Panse, V. G. (1935). *Ind. J. Agric. Sci.* **5**, 523.
Immer, F. R. (1932). *J. Agric. Res.* **44**, 649.
Justesen, S. H. (1932). *J. Agric. Sci.* **22**, 366.
Kalamkar, R. J. (1932). *J. Agric. Sci.* **22**, 373.
McClelland, C. K. (1929). *J. Amer. Soc. Agron.* **21**, 524.
——————— (1934). *J. Amer. Soc. Agron.* **26**, 491.
Yates, F. (1933). *Emp. J. Expt. Agric.* **1**, 129.

Appendix

Experiment 1B/33G, cotton varieties, irrigated

The experiment was surrounded by bulk cotton on three sides and another cotton varietal trial on the fourth.

Area of each plot :

(1) Margins included, 18 ft. × 19 ft. 6 in. = 0·00806 acre.

(2) Margins excluded, 14 ft. × 15 ft. 6 in. = 0·00498 acre.

Plots with margins excluded are 61·8 per cent of those with margins included.

Varieties : Mollisoni
Cwn. 520
0/10/26·1
P. 289 F
P. 289 F_1
P. 285 F_2
New Ashmouni

Layout—Four randomised blocks in two rows.

Experiment 4B/33G, cotton varieties, irrigated

The experiment had another cotton varietal trial and bulk cotton on one side and only one row of *desi* cotton with vacant space beyond on the other. A path two feet wide ran along the ends of experimental rows.

Area of each plot :

(1) Margins included, 18 ft. × 35 ft. = 0·0145 acre.

(2) Margins excluded, 14 ft. × 31 ft. = 0·01 acre.

Plots with margins excluded are 69·0 per cent of those with margins included.

Varieties : Roseum
N. T. 10
Mollisoni
Desi
Malvi

Layout—Six randomised blocks in two rows.

NOTE.—Since the end plots, both of Malvi, in blocks 1 and 4 were not well protected by extra rows beyond and the yield figures for these plots with their margins included were high, their yields estimated by the missing plot technique have been used in the statistical analysis.

Experiment 1/33D, pre-sown and rain-sown American and Desi cotton, irrigated

The experiment was not surrounded by any crop.

Area of each plot :

(1) Margins included, 14 ft. × 15 ft. = 0·00482 acre.

(2) Margins excluded, 4 ft. 8 in. × 9 ft. = 0·000964 acre.

Plots with margins excluded are 20·0 per cent of those with margins included.

Varieties and treatments : Cambodia, Indore 25, pre-sown.
Malvi 9, pre-sown.
Cambodia, Indore 25, rain-sown.
Malvi 9, rain-sown.

Dates of sowing— Pre-rain on 29th May 1933.
On rains on 22nd June 1933.

Layout— Latin square 4 × 4.

Experiment 2/33D, cotton varieties, dry

The experiment was surrounded by a road on three sides and there was bulk cotton at some distance from the experiment on the fourth.

Area of each plot :

(1) Margins included, 11 ft. 8 in. × 68 ft. 3 in. = 0·0183 acre.

(2) Margins excluded, 7 ft. × 62 ft. 3 in. = 0·01 acre.

Plots with margins excluded are 54·6 per cent of those with margins included.

Varieties : Malvi 1
Malvi 3
Malvi 5
Malvi 8
Malvi 9
Local

Layout—Six randomised blocks in two rows.

NOTE.—Two end plots of Malvi 1 and Malvi 3 in blocks 3 and 6 were on the road side and two more plots of Malvi 8 and local at the other end had also extra vacant space beyond. The yield of all these four plots with margins included was abnormally high, so that their yields estimated by the missing plot technique have been used in the statistical analysis.

Experiment V31/34I, cotton varieties, dry

The experiment had two guard rows on outer side of the edge plots.
Area of each plot :

(1) Side margins included, 18 ft. 8 in. × 31 ft. = 0·0133 acre.
(2) End margins included, 14 ft. × 39 ft. = 0·0126 acre.
(3) Margins excluded, 14 ft. × 31 ft. = 0·01 acre.

Plots with margins excluded are 75·2 per cent of those with side margins included and 79·4 per cent of those with end margins included.

Varieties : Cwn 520
Malvi 9
Roseum
Local
G. 16
Malvi 1
G. 51

Layout—Six randomised blocks in three rows.

Experiment 2V12/34I, wheat varieties, dry

The experiment had two guard rows on the outer side of the edge plots.
Area of each plot :

(1) Both side and end margins included, 16 ft. 4 in. × 37 ft. =0·0139 acre.
(2) Side margins included, 16 ft. 4 in.× 31 ft. = 0·0117 acre.
(3) Margins excluded, 14 ft. × 31 ft. = 0·01 acre.

Plots with margins excluded are 85·5 per cent of those with side margins included.

Varieties : Punjab 8A
Punjab 9D
Cross 591
Pusa 114
C. P. 115
Bansi 224
Bansi Pili 808
Local

Layout—Six randomised blocks in three rows.

HYBRID VIGOUR IN WHEAT*

BY

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AND

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A SUMMARY

BY

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I. INTRODUCTION

A proper understanding of hybrid vigour or heterosis is of importance both from the academic and the practical viewpoint : from the former because herein lies one of the profoundest mysteries in genetics, from the latter because breeding policy must be regulated according to whether or not vigour of the outstanding order sometimes found in the F_1 can be " captured " as a homozygous segregate. Though the scientific interest of hybrid vigour is of long standing, the extensive literature on the subject is characterised by some unsatisfactory features, the most fundamental being inadequacy of the numerical evidence. Further, it is often impossible to tell exactly what is meant by " selfing " : the pollen applied to a selfed plant may have been obtained from the plant itself or from another plant of the same " selfed " line.

Within recent years hybrid vigour has been exploited with a certain measure of success by plant-breeders. In some crops notably in maize, tobacco and tomato, crossed seed can be obtained with ease in such quantity as to make it practicable to grow a commercial crop of F_1 plants. Substantial yield increases by this means have been claimed.

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*This paper is an abbreviated account of ' Investigations on yield in the cereals. VIII. Hybrid vigour in wheat ' by F. L. Engledow and B. P. Pal, published in *J. Agric. Sci.* 1934 : **24** : 390-409. The writer is obliged to Prof. Engledow and to the Editors of the *Journal of Agricultural Science* for permitting the publication of the article in this form.

Although it would be impracticable to grow commercial crops of F_1 plants of a self-pollinating plant, such as wheat, it might be possible theoretically, assuming hybrid vigour is shown by this plant, to increase yields by regularly raising crops of, it may be, F_5 or F_6 plants. Upon consideration of all the circumstances it was decided to look for and study hybrid vigour in wheat. Comparisons of F_1 plants with the parents are limited in range by the difficulty of obtaining sufficient seed by crossing. It was therefore decided to work along two separate lines: first, to make an intensive study of one cross; concurrently to explore possibilities by comparing small F_0 and F_1 populations for a large range of crosses. In all cases development was studied by the easily determined but valuable index, rate of tiller formation, since an increase in 'vigour' as judged by final yield could not be interpreted without growth data.

II. Experimental work

(*a*) *Statistical comparison of F_1, F_2 and F_3 with the parent forms*

Little Joss (alternatively called Joss), a red smooth-chaffed variety, and Thule, white rough-chaffed variety, of *Triticum vulgare*, were reciprocally crossed. The growings were:

Generation	*Year*	*Plot layout*
The reciprocal F_1's and both parents.	1929-30	A 4 × 4 Latin square with 108 seeds per plot.
F_2 and both parents (the F_2 was an equal mixture of the seeds set by the reciprocal F_1's).	1930-31	A 4 × 4 Latin square with 560 seeds per plot. The Latin square was sown in duplicate.
F_1's and both parents . . .	1931-32	In each case a 4 × 4 Latin square with 162 seeds per plot.
F_2's and both parents		
F_3's and both parents.		

In the plots the sowing interval was 8 × 2 in.

(*b*) *Small-scale observational comparisons of the F_1 and the parents for a large range of crosses*

The F_1 population was of about twenty-five plants only, so that although actual measures of germination, tillering and yield were made, the data cannot be examined statistically. It was hoped that these experiments might reveal some

cases of marked hybrid vigour and show the relative value of parental forms in relation to the phenomenon. The crosses were in four groups, *viz* :—

Between varieties of *T. vulgare* (21 chromosomes)*.
Between varieties of species with 14 chromosomes.
Between varieties of species with 21 chromosomes.
Between the 14 and 21 chromosomes species.

In almost all cases reciprocal crosses were made.

(*c*) *Physiological experiments*

Comparisons of F_1 and parents were made in respect of embryo weight, rate of dry weight increase, and rate of respiration of germinating grains. The respiration experiments were very kindly carried out by Dr. H. R. Barnell.

The effect upon grain development and germination of covering the ear with a waterproof paper bag during hybridising was studied, as also the alleged effect upon vigour of the act of hybridising (" regeneration ") when plants of the same variety are used as parents.

III. Detailed study of the cross Little Joss × Thule†

As explained in section II, reciprocal crosses were made between these two varieties and the F_1, F_2 and F_3 generations were compared with the parents. In 1931-32 there were daily counts of germination and of rate of leaf formation. In this and in the other two crop-years also, some observations on tillering and determinations of final yield of grain were carried out.

Germination.—The initial differences between the parents themselves and between the two (reciprocal) F_1's were not significant but at every germination count the F_1 values were significantly greater than those for either parent, in most cases at the 100 : 1 point and in all cases at the 20 : 1 point at least.

Leaf formation.—Counts made in 1931-32 showed the F_1 populations to be in advance of both parents in rate of leaf formation (prior to the commencement of tillering). The F_2 from Joss × Thule had significantly more leaves than either parent, but the reciprocal F_2 exceeded only the Thule parent. Both the F_3 generations were significantly greater than Thule but not significantly greater than Joss.

Tillering.—Tillering, taken to mean number of side shoots (*i.e.*, additional to the main axis of the plant), gave results which, for all the counts made, are shown fully in Table I. The essential differences are set out below where T = Thule, J = Little Joss, J×T = Fx Joss × Thule, T×J = F_x Thule × Joss, $>$ = significantly greater at 100 : 1 point and ($\gtrdot$) = significantly greater between the 20 : 1 and 100 : 1 points. While many actual differences in Table I are not statistically

* The haploid number of chromosomes is referred to.

† In naming the parents of a cross, the female is always written first in this paper.

significant the constancy of the sign in some cases, for instance, the difference between the reciprocal F_1's in 1929-30, deserves to be noticed.

F_1 J × T	> T	at	6	out of 6	counts in 1929-30.
	> T	,,	1	,,	1 count in 1931-32.
	> J	,,	2	,,	6 counts in 1929-30.
	> J	,,	1	,,	1 count in 1931-32.
	> F_1 T×J	,,	2	,,	6 counts in 1929-30.
	> F_1 T×J	,,	1	,,	1 count in 1931-32.
F_1 T × J	> T	at	6	out of 6	counts in 1929-30.
	> T	,,	1	,,	1 count in 1931-32.
	< J	,,	2	,,	6 counts in 1929-30.
	> J	,,	1	,,	1 count in 1931-32.
	< F_1 J×T	,,	2	,,	6 counts in 1929-30.
	< F_1 J×T	,,	1	,,	1 count in 1931-32.
F_2 J × T	> T	at	4	out of 4	counts in 1930-31.
	> T	,,	1	,,	1 count in 1931-32.
	< J	,,	4	,,	4 counts in 1930-31.
	< J	,,	0	,,	1 count in 1931-32.
	> F_2 T×J	,,	1	,,	4 counts in 1930-31.
	(>) F_2 T×J	,,	1	,,	1 count in 1931-32.
F_2 T×J	> T	at	4	out of 4	counts in 1930-31.
	> T	,,	1	,,	1 count in 1931-32.
	< J	,,	4	,,	4 counts in 1930-31.
	< J	,,	1	,,	1 count in 1931-32.
	(<) F_2 J×T	,,	1	,,	4 counts in 1930-31.
	(<) F_2 J×T	,,	1	,,	1 count in 1931-32.
F_3 J×T	> T	at	1	out of 1	count in 1931-32.
	< J	,,	1	,, 1	,, 1931-32.
	> F_3 T×J	,,	0	,, 1	,, 1931-32.
F_3 T×J	> T	at	1	out of 1	count in 1931-32.
	< J	,,	1	,, 1	,, 1931-32.
	< F_3 J×T	,,	0	,, 1	,, 1931-32.

For the parents J > T at all the thirteen counts in three years combined, and significantly so in eleven of them.

TABLE I

Average number of side tillers per plant (i.e., *not counting the main axis*) *in Joss, Thule, and their* F_1, F_2 *and* F_3 *generations. The numbers are expressed on the basis of the general mean* (*of the two parents and the two hybrid generations*) = *100.*

Date of count	Joss	Thule	Joss × Thule	Thule × Joss
		F_1 1929-30		
25th January . . .	113·4	56·7	119·8	111·5
1st February . . .	111·1	66·8	116·6	107·5
15th February . . .	114·1	64·2	116·5	105·0
1st March	109·9	63·2	120·2	106·5
15th March	109·5	70·9	114·3	105·3
8th August (harvest) . .	109·1	93·9	101·0	97·0
		F_1 1931-32		
23rd February . . .	92·5	64·3	123·4	119·7
		F_2 1930-31		
27th January . . .	148·4	34·4	123·0	95·1
17th February . . .	120·7	77·5	102·4	100·0
18th March	135·4	67·0	99·7	98·3
16th April	113·4	82·3	104·4	99·7
		F_2 1931-32		
25th February . . .	115·7	71·8	110·9	101·7
		F_3 1931-32		
26th February . . .	121·1	75·5	103·7	99·9

Yield.—Yield in the form of weight of grain per unit area is given in Table II. Although in sowing the spacing was the same in all plots, an acceptable measure of average yield per plant could not be obtained, for mortality, and therefore, effective spacing, was not the same in all four populations [two parents

and two (reciprocal) hybrids). Employing the same notation as for tillering, the significant differences were :

F_1 J × T > T in 1931-32.
> J „ „
F_1 T × J > T in 1931-32.
> J „ „
F_2 J × T > T in 1931-32.
F_2 T × J > T „ „
F_3 No differences significant.
J > T in 1931-32 (in the comparisons of F_1 and F_2 but not of F_3).

TABLE II

Yield of grain (air-dry) per unit area of Joss, Thule, and their F_1, F_2 and F_3 generations. The yields are expressed on the basis of the general mean (of the two parents and the two hybrid generations) = 100.

Year	Joss	Thule	Joss × Thule	Thule × Joss
		F_1		
1929-30	103·9	88·3	104·0	103·7
1931-32	97·5	83·8	111·3	107·4
		F_2		
1930-31	106·6	98·3	94·6	100·0
Duplicate sowing . . .	106·6	95·1	97·7	100·7
1931-32	110·1	81·6	104·1	104·3
		F_3		
1931-32	110·7	95·6	98·9	96·1

In most of the previously published experiments on hybrid vigour the data do not allow of comparison between season and season. There is a noteworthy exception in Bredemann and Heuser [1931] who in a comprehensive six-year experiment with rye were impressed by differences in vigour from year to year. Tables I and II show that for F_1 in 1929-30, Joss × Thule exceeded both parents and its reciprocal in tillering and also in yield, the reciprocal being intermediate between the parents. In 1931-32, however, the F_1's for both directions of the cross exceeded both the parents in tillering and also in yield.

IV. Comparative vigour of the F_1, F_2 and F_3 generations, and of the reciprocal directions, of the cross Little Joss × Thule

For convenience, the reciprocal directions of the cross will be considered first. In the F_1 generation no differences were found in respect of germination and early leaf formation. Constant observation, however, gave rise to the impression that the F_1 J × T was growing, and in particular tillering, far more vigorously than its reciprocal. Periodic counts showed, however, that the tillering difference was significant on only three out of seven occasions in the 1929-30 and 1931-32 crops combined. As Table I shows, the difference had on all seven occasions the same sign, and since the plots were only four times replicated, it may be inferred that the one direction of the cross showed a small but certain increase in vigour of tillering over the other direction. This difference however was not followed up by a difference in yield per unit area. For the F_2 generation there is slight evidence for the superior early leaf formation and tillering of J × T as compared with T × J but no yield difference between them. The reciprocal F_3's showed no significant differences at all.

Taking the F_1, F_2 and F_3 generations together, it is seen that reciprocal differences are fairly common but never large. But it is important to observe that every significant difference is in the same direction, *viz.*, J × T > T × J. Observations made by eye all through the growing period gave rise to the impression that this directional superiority was well marked though far more apparent in the first five or six months than in later life.

The relative vigour of the successive generations in respect of early leaf formation (for germination the data is for F_1's and parents only), tillering and yield indicates that there was a steady decline, *i.e.*, F_0 $F_1 > F_2 > F_3$.

V. Observations on a wide range of crosses: various phenomena connected with hybridity

The exploratory purpose of a wide range of crosses, each on a scale not large enough for strict statistical examination, has been explained in Section II. The full list of the parents used in the crosses is given in (*4*) of this Section. The main trends of the results will be given in spite of the limitation of statistically low numbers of observations. For, on the one hand, it is difficult to make really adequate numbers of crosses; and on the other, one of the chief clues to the nature of the obscure phenomenon of hybrid vigour is to settle its range of occurrence.

(*1*) *Crossability.*—In hybridising wheats the general impression was obtained that even among closely related forms having the same chromosome number it is easier to cross some varieties than others. Moreover a larger proportion of hybrid grains to florets pollinated was in some cases obtained in one direction of the cross

than in the other. In crosses where the parents mature their anthers at considerably different times, differences in crossability between the reciprocal directions may, perhaps, be simply explained. But in other crosses where no doubt was occasioned by time of anther maturation, certain varieties always proved more successful as female than as male parents.

(2) *Xenia* (*grain weight effects*).—Table III gives the results from the crosses now under discussion. Their trend suggests that in inter-varietal (*T. vulgare*) crosses, the crossed grain is usually heavier than that of one or other of the parents and often heavier than both. In the other categories of crosses there is a general tendency to decrease below the parental values.

TABLE III

The relative weight of the crossed grain and of the grains of the parent forms. A cross and its reciprocal are separately entered. The crosses were made in 1932. The upper line of each entry in the table gives the number of crosses concerned, the lower (in brackets) the limits of the increase per cent over the stated or the larger-grained parent (F_0) or of the decrease per cent below the smaller-grained parent.

	Crosses between hexaploid wheats (all *T. vulgare*)	Interspecies crosses of tetraploid wheats	Interspecies crosses of hexaploid wheats	Interspecies crosses of tetraploid and hexaploid wheats
Decrease below both F_0's	6	9	4	3
	(1-35)	(2-47)	(8-23)	(14-58)
Increase over $F_0♂$ but not over $F_0♀$	4	5	7	*Nil*
	(13-49)	(8-20)	(1-73)	
Increase over $F_0♀$ but not over $F_0♂$	11	2	3	*Nil*
	(2-46)	(2-18)	(3-36)	
Increase over both F_0's	13	2	3	*Nil*
	(1-24)	(1-2)	(4-21)	
Total crosses made	34	18	17	3

Examination of the results suggests that the occurrence of crossed grains of weight greater than the parental grains is not correlated with the grain size of the male parent.

One of the *vulgare* wheats here used, Tom Thumb, produced characteristically shrivelled grain. The grain it set when pollinated with strongly-growing English varieties of *T. vulgare* were invariably shrivelled and poorly filled. In contrast the *T. vulgare* forms, Chinese White and Iron gave, in all the crosses in which they were the female parent, excellently filled grain.

(3) *Tillering and yield of* F_1 *and* F_0.—Although actual counts were made as checks upon eye-impressions they cannot be used here because of the smallness of the plant populations concerned. The general conclusion was that most of the F_1's tillered more profusely than their parents, the difference in some cases being very striking indeed. In yield also there appeared to be differences harmonious with those in tillering. The cross, Little Joss × Yeoman, was in two seasons an apparently outstanding example of hybrid vigour in F_1.

(4) *The influence of certain varieties as parents.*—The parents used for this series of crosses were :—

Tetraploid	Hexaploid
Emmer (*T. dicoccum*)	White Spelt (*T. spelta*).
Persian Black (*T. persicum*)	American Club (*T. compactum*).
Kubanka (*T. durum*)	Sphaerococcum (*T. Sphaerococcum*).
Polish (*T. polonicum*)	Red Fife (*T. vulgare*).
Rivet (*T. turgidum*)	Squarehead's Master (*T. vulgare*).
	Little Joss (*T. vulgare*).
	Yeoman (*T. vulgare*).
	Red Marvel (*T. vulgare*).
	Hen Gymro (*T. vulgare*).
	Old Fashioned 2 (*T. vulgare*).
	Tom Thumb (*T. vulgare*).
	Victor (*T. vulgare*).
	Iron (*T. vulgare*).
	Thule (*T. vulgare*).
	Chinese White (*T. vulgare*).

In most cases the cross was made reciprocally and counting a cross and its reciprocal separately, the number of crosses was :—

T. vulgare × *T. vulgare*—56.

Hexaploid species × hexaploid species—17.

Tetraploid species × tetraploid species—18.

Hexaploid species × tetraploid species—3.

It was concluded that some of the varieties influence their F_1 progeny in characteristic ways. The outstanding examples occurred in the *T. vulgare* × *T. vulgare* crosses. Red Marvel, Iron and Old Fashioned 2, whether used as male or female parents, gave in all their crosses, F_1's of markedly lower tillering capacity than the higher tillering of the two parents. Tom Thumb as a female parent, always gave poor F_1's : as male parent it gave very vigorous progeny. The outstanding variety was Chinese White, its F_1's being always very vigorous (for tillering) whether it was used as male or female parent. It was concluded that no general connection subsisted between the vigour of tillering of the parent

varieties and of the resulting F_1. These results reinforce the view of some other investigators [*e. g.*, Jenkins, 1929] that some varieties characteristically give vigorous and others feeble F_1's. Taken with the additional conclusions that some varieties give much better F_1's in one direction than in the reciprocal direction of a cross, it opens an approach, albeit lengthy, to the nature and causes of hybrid vigour.

VI. Physiological aspects

(*1*) *Embryo weight.*—This was studied in the Joss × Thule cross, using ten grains for each parent and for each of the reciprocal directions of the cross, and also in the Joss × Yeoman cross, using 120 grains (12 lots of 10 each) of each of the four categories. The latter cross though not studied in full like the former, appeared to give an exceptionally vigorous F_1. The seeds were placed on layers of filter paper in Petri dishes, just covered with distilled water, and kept for twenty-four hours in an incubator at 23°C. Upon removal the seeds were dried (surface moisture) with filter paper, and weighed. Then the embryos were dissected out and weighed (=fresh weight of embryo) and finally after twenty-four hours in an oven at about 100°C. they were again weighed (=dry weight of embryo). In each case the dry weight of the embryo was the same for crossed grains as that formed by the female parent on normal selfing. The position therefore appears to be different from that in maize where Ashby [1930, 1932] found greater initial weight in hybrid embryos as compared with parental embryos. However Ashby's conclusion that there is no acceleration of growth rate in maize hybrids exhibiting hybrid vigour, the latter phenomenon being attributed to the larger 'capital' with which the hybrid embryo commenced life, has been recently questioned by Lindstrom [1935]. Lindstrom reduced the 'capital' of young hybrid plants by decapitation and found that despite this handicap the hybrids overtook the growth of the untouched parental lines, indicating that the hybrids had a faster growth rate.

(*2*) *The effect of artificial selfing.*—To find out whether the technique of crossing favoured in any way either the selfed grain of the parents or the crossed grain, both naturally and artificially selfed seed of six wheat varieties was obtained under the same growing conditions for all. Artificial selfing was carried out in exactly the same way as artificial crossing, save for the kind of pollen used. It was found that though the rate of germination was more rapid for the artificially selfed seed in the case of five varieties, the total germination was the same for both kinds of selfed seed. The slight "lead" obtained by the former by its earlier germination was not maintained.

(*3*) *Respiration rates of germinating grains, hybrid and parental.*—Measurements of respiration of germinating grains by the Pettenkofer method were very kindly made by Dr. H. R. Barnell. He used the parental and reciprocally crossed grains of the Joss × Thule cross, which as described in Sections III and IV showed

a small but securely demonstrated degree of ' hybrid vigour ' in F_1. It was possible to give only ten grains of each of the hybrid seeds. From the results it was possible to infer that up to 180 hours from the time of putting the grains in water the more vigorous parent, Joss, has a decidedly lower respiration rate than Thule ; and further, that both kinds of crossed grain respire at about the same rate as Thule.

Experiments were also made on rate of dry weight increase of the growing embryo. The results were not in harmony with either the respiration results or with the idea that hybrid vigour in wheat is controlled, as Ashby concluded it to be in maize, by initial embryo weight.

(4) *Some general inferences.*—An examination was made of the whole of the literature bearing upon hybrid vigour and a list was assembled of all the crosses in which the phenomenon appears to have been clearly shown. Admissibility of evidence has had to be determined from the recorded circumstances, for the cases are few indeed in which trustworthy numerical evidence is given. Of the apparently sound cases fourteen are for crosses among varieties of the same species, the species involved being : *Zea Mays*, *Z. saccharata*, *Andropogon Sorghum*, *Secale cereale*, *Solanum melongena*, *Lycopersicum esculentum*, *Petunia violacea*, *Digitalis purpurea*, *Minulus luteus*, *Viola tricolor*, *Dianthus caryophyllus*, *Nemophila insignis*, *Brassica oleracea*, *Soja max*.

Of interspecies crosses in which hybrid vigour seems to have been shown clearly there are twenty-nine cases involving two or more species of the following genera : *Solanum*, *Datura*, *Petunia*, *Lycium*, *Nicotiana*, *Verbascum*, *Digitalis*, *Pentstemon*, *Malva*, *Althaea*, *Lavatera*, *Tropaeolum*, *Cucumis*, *Lobelia*, *Mirabilis*.

So far as this list goes there is evidence that hybrid vigour occurs preponderantly in crosses among parents which are (*a*) diploid, (*b*) naturally out-pollinating, (*c*) endospermic in seed. The significance of the association of these with hybrid vigour cannot yet be judged.

VII. Summary

An intensive investigation of hybrid vigour in the cross Little Joss × Thule (both varieties of *T. vulgare*) in the F_1, F_2, and F_3 generations was made. In addition a range of ninety-four crosses was studied on a small scale ; of these fifty-six were between varieties of *T. vulgare*, the remainder being interspecies, some with parents of the same chromosome number and some not. " Vigour " variously specified by investigators, was here taken to be yield of grain together with the associated attribute, tillering. Certain physiological experiments were also made on grain weight, germination rate, embryo weight and respiration rate of the germinating grain. The crossses were made reciprocally.

Clear evidence of hybrid vigour was displayed in the cross Little Joss × Thule, though the manifestation was not so striking as, for example, in maize.

Between the reciprocal directions of the cross, small but statistically certain differences were established in F_1 : in F_2 there were slight indications of difference, the F_3's were identical in vigour.

Vigour in the successive hybrid generations as compared with the parents (F_0) was clearly in the order $F_0 < F_1 > F_2 > F_3$.

From the wide range of crosses a number of general inferences was drawn (1) In some varieties a restricted optimum period for crossing was found. (2) Certain wheats regularly proved more successful (proportion of successful pollinations) as female than as male parents. (3) In crosses of *T .vulgare* × *T. vulgare* the actual crossed grain was in most cases of greater weight than that of one parent and often heavier than either. With interspecies crosses, however, even when the parents had the same chromosome number, decrease instead of increase was found in most cases. (4) An F_1 of greater tillering capacity and yield than its parents resulted from most of the crosses. (5) But there were important exceptions and certain varieties stood out as good or bad, in respect of vigour of F_1 progeny, when used as male parent or female or in both directions of crossing.

From the physiological experiments it was clear that Ashby's explanation of hybrid vigour in maize F_1's as resulting solely from the greater embryo weight of the crossed grain, was inapplicable to wheat. No increase in weight over parental embryo weight occurred. Measurements of respiration rate gave further evidence against the possibility that embryo weight influences hybrid vigour in wheat.

From examination of all the published cases of hybrid vigour it appears that the phenomenon occurs preponderantly in crosses among parents which are (*a*) diploid, (*b*) naturally out-pollinating and (*c*) endospermic in seed.

REFERENCES

Ashby, E. (1930). *Ann. Bot.* **44**, 457.
——— (1932). *Ann. Bot.* **96**, 1007.
Bredemann, G., and Heuser, W. (1931). *Zeit. Zuchtung* **A. 16**, 1.
Jenkins, M. T. (1929). *J. Agric. Res.* **39**, 677.
Jones, D. F. (1918). *Cornell Agric. Expt. Stn. Bull.* No. **207**.
Lindstrom, E. W. (1935). *Amer. Nat.* **69**, 68.

A NOTE ON THE CLASSIFICATION OF INDIAN SAFFLOWER

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I. Introduction

Excepting the pioneer work of Howard, Howard and Khan [1915] and the supplementary note by Khan [1929], there is no other literature available on the classification of Indian safflower (*Carthamus tinctorius* L.). Both these works were found helpful in the isolation and identification of the types by the writers, during the course of their investigation on this crop.

While studying the botanical characters of the safflower types the writers, however, felt that some of the characters used by Howard, Howard and Khan in their classification were not sufficiently clear. Their classification was based on rather broad divisions of the plant characters.

For example, the spinose and spineless types are grouped in one common class II " Outer bracts ovate to rounded, moderately spinose to spineless ", of the key. Similarly the Types 9, 15, 16, 18 and 21 with lanceolate and spinose bracts and the Types 29, 30, 31, 32, 33 and 34 with lanceolate and spineless bracts, as mentioned in the description of these types, have also been included in this class. Again, such characters as (1) ' moderately spinose ', (2) faint red dot at the apex in Types 28 and 29, (3) trace of red near the apex in Type 14, and (4) presence of red streaks on the sides of the flower buds in Types 29, 30, which are not sufficiently clear, are used in the key. Such characters are therefore likely to be misused. It was

observed that red colour in the form of red streaks or red splashing, noticed in the flower buds of some of the types, was probably due to aphis attack, although these types were normally free from such red colouration.

Besides, the twenty-nine new types which were discovered by the writers during the course of their investigations could not be fitted in the classification of Howard Howard and Khan.

The revision of the classification of Indian safflower is therefore attempted by the writers, using the classification of Howard, Howard and Khan as its basis. In their revised classification single and distinctive characters are used, indefinite terms are as far as possible avoided, and its scope is enlarged by the inclusion of the twenty-nine new types.

The original numbers of the Pusa types have been retained and supplementary characters of diagnostic importance are noted under each. The new types have their diagnostic characters described in detail. Owing to the re-distribution of the Pusa types and retention of their original numbers serial order of the types could not be kept either in the key or in the description of the types.

Finally the writers express their indebtedness to Dr. F. J. F. Shaw, Imperial Economic Botanist, for his helpful suggestions.

II. Key to the types

1. Bracts spinose

(1) Outer bracts lanceolate.

(A) Inner bracts smooth and green.

(*a*) Florets white.

Plants erect—Type 1.

Plants spreading—Types *35*, *36*, *37*.

(*b*) Florets yellow, turning to brownish yellow on fading.

Plants erect—Type *38*.

Plants spreading—Types 2, 3, 4.

(*c*) Florets yellow, turning to red on fading.

Plants erect—Types 25, *39*, *40*, *41*, *42*.

Plants spreading—Types 5, 6, 7, 20, 21, 23, 26, 27, 28, *43*, *44*, *45*, *46*, *47*, *48*.

(*d*) Florets reddish orange, turning to red on fading.

Plants erect—Type *49*.

N.B.—The types in Italics are new ; the rest are Pusa types.

(B) Inner bracts felted and white.

(*a*) Florets white.

Plants erect—Type *50*.

(*b*) Florets yellow, turning to brownish yellow on fading.

Plants erect—Type 9.
Plants spreading—Types *51*, *52*.

(*c*) Florets yellow, turning to red on fading.

Plants erect—Type *53*.
Plants spreading—Types 15, 16, *54*.

(*d*) Florets deep red.
Plants erect—Type *55*.

(2) Outer bracts obovate to rounded.

(A) Inner bracts smooth and green.

(*a*) Florets yellow, turning to red on fading.

Plants erect—Types 19, 22.
Plants spreading—Types *56*, *57*.

(*b*) Florets deep red.

Plants erect—Type 24.
Plants spreading—Type *58*.

(B) Inner bracts felted and white.

(*a*) Florets white.

Plants erect—Type *59*.

(*b*) Florets yellow, turning to brownish yellow on fading.
Plants spreading—Type 8.

(*c*) Florets yellow, turning to red on fading.
Plants erect—Types 10, 12, 13, 14, *60*.

2. Bracts spineless

(1) Outer bracts lanceolate.

(A) Inner bracts smooth and green.

(*a*) Florets orange yellow, turning to red on fading.
Plants erect—Types 29, 30.
Plants spreading—Types 31, 32, 33, 34.

(2) Outer bracts obovate to rounded.

(A) Inner bracts smooth and green.

(*a*) Florets yellow, turning to orange red on fading.

Plants erect—Type 18.

(B) Inner bracts felted and white.

(*a*) Florets white.

Plants erect—Type *61*.

(*b*) Florets yellow, turning to red on fading.

Plants erect—Types 11, *62*.

(*c*) Florets deep red.

Plants erect—Type 17.

Plants spreading—Type *63*.

III. Descriptions of the types*

I. Bracts spinose, outer lanceolate, inner smooth and green

(*a*) *Florets white*

Type 1.—Plants tall, above 130 cm. in height. Bracts with apical spines and without hairs. Maturity late.

Type 35.—Habit spreading. Plants intermediate in height, about 115 cm. high. Leaves dark green, deeply incised, 18-21 × 4·5-5 cm. Bracts leafy, lanceolate, spiny. Florets white, changing to dirty white. Maturity late.

Type 36.—Habit spreading. Plants short, less than 95 cm. in height. Leaves dark green, slightly incised or sometimes dentate, 16-19 × 4·5-5 cm. Bracts and florets as in Type 35. Maturity late, but earlier than in Type 35.

Type 37.—Habit spreading. Plants intermediate in height, about 105 cm. high. Leaves incised, darker than in Type 36, 17-19 × 4-4·5 cm. Bracts as in Type 36 but narrower and shorter. Florets as in Type 35. Maturity late.

(*b*) *Florets yellow, changing to brownish yellow on fading*

Type 2.—Plants intermediate in height, about 115 cm. high. Leaves slightly incised or deeply dentate. Maturity intermediate.

Type 3.—Plants intermediate in height, slightly taller than in Type 2. Maturity early.

*Plants up to 100 cm. high are termed short, 100-130 cm. intermediate and above 130 cm. tall. Plants maturing within 150 days are termed early, those maturing within 150-160 days intermediate and those maturing after 160 days late. The descriptive notes on the Pusa types have been confined to supplementary characters of diagnostic importance.

Type4.—Plants short, about 95 cm. high.

Type 38.—Habit erect. Plants tall, height 130 cm. Leaves light green, with few short marginal spines, serrate, 15-18 × 3-5 cm. Bracts lanceolate, green, spinose with long spines. Florets very light yellow, turning to light red on fading. Maturity late.

(c) *Florets yellow, turning to red on fading*

Type 5.—Plants intermediate in height, about 115 cm. high. Maturity early.

Type 6.—Plants tall, about 145 cm. in height. Leaves light green, serrate to dentate. Maturity very early.

Type 7.—Plants tall, about 135 cm. high. Leaves light green, lighter than in Type 6, serrate to dentate. Maturity early.

Type 18.—Plants tall, about 145 cm. in height. Bracts slightly spiny. Florets yellow, turning to orange red on fading. Maturity late.

Type 20.—Plants tall, erect and compact, between 100 and 140 cm. high. Maturity early.

Type 21.—Plants intermediate in height, about 125 cm. high. Leaves serrate to dentate. Florets yellow, turning to orange red on fading. Maturity intermediate.

Type 23.—Plants intermediate in height, about 105 cm. high. Bracts lanceolate to elliptical, green and slightly spiny. Maturity intermediate.

Type 25.—Habit somewhat erect or tending to be spreading. Plants intermediate in height, about 115 cm. high. Maturity early.

Type 26.—Plants very short, about 80 cm. high. Maturity early.

Type 27.—Plants short, about 100 cm. high. Bracts, flower buds and florets as in Type 26, but the red dot at the apex of the flower buds less distinct. Maturity early.

Type 28.—Plants intermediate in height, about 115 cm. high. Florets yellow, turning to orange red on fading. Maturity early.

Type 39.—Habit erect. Plants intermediate in height, about 125 cm. high. Leaves light green, incised, 24-27 × 6·5-7 cm. Bracts lanceolate to elliptical, rarely rounded, smooth, green and slightly spinose. Flower buds yellow with red base and red tip. Florets yellow, changing to red on fading. Maturity late.

Type 40.—Habit erect. Plants tall, 100-130 cm. in height. Leaves dark green, broadly dentate. Bracts lanceolate, long, green, smooth and spinose. Flower buds yellow. Florets yellow, turning to red on fading. Maturity late.

Type 41.—Habit erect. Plants tall. 100-140 cm. in height. Leaves light green serrate. Bracts lanceolate, long, green, and smooth and spinose. Flower buds yellow. Florets yellow, turning to red on fading. Maturity very late.

Type 42.—Habit erect. Plants tall, 100-140 cm. in height. Leaves very large, incised, green. Outer bracts lanceolate with a few short spines. Inner bracts obovate to rounded, green, smooth, with a few short spines. Flower buds deep yellow. Florets deep yellow, turning to red on fading. Maturity late.

Type 43.—Habit spreading. Plants short, about 95 cm. in height. Leaves light green and serrate, 14-16 × 4-5 cm. Outer bracts lanceolate, very long and with long spines. Flower buds yellow with reddish splashing on the sides and tips yellow without red dot at the apex. Florets yellow, fading to orange red. Maturity early.

Type 44.—Habit spreading. Plants short, 80-100 cm. high. Leaves green, broadly dentate, 18-22 × 6-6·5. Bracts lanceolate, short but broad, and green. Flower buds yellow, turning to red on fading. Maturity intermediate.

Type 45.—Habit spreading. Plants intermediate in height, about 105 cm. high. Leaves light green, broadly dentate, 17-22 × 5-6 cm. Bracts—outer lanceolate to elliptical, and inner lanceolate or obovate to rounded, green and spinose. Florets yellow, changing to red on fading. Maturity late.

Type 46.—Habit spreading. Plants short, about 95 cm. high. Leaves light green and serrate, 17-18·5 × 4·5-5·5 cm. Bracts as in Type 23. Flower buds with distinct red base and yellow tip. Florets reddish yellow or orange from the start and red on fading. Maturity intermediate.

Type 47.—Habit spreading. Plants short, about 100 cm. in height. Leaves green, dentate to serrate. Bracts lanceolate, smooth, green and spiny, 14-15 × 3·5-4 cm. Flower buds yellow with red splashing at the base and red towards the tip with yellow apical dot. Florets reddish yellow, changing to red on fading. Maturity intermediate.

Type 48.—Habit spreading. Plants short, about 85 cm. high. Leaves light green, serrate or slightly dentate, 14-16 × 4·5. Bracts lanceolate, green and spinose. Flower buds with distinct red base, reddish below the apex and with no red dot at the apex. Florets yellow, turning to red on fading. Maturity intermediate.

(*d*) *Florets reddish orange, changing to red on fading*

Type 49.—Habit erect. Plants intermediate in height, about 115 cm. high. Leaves green, deeply incised, 26-35 × 6-13 cm. Bracts lanceolate, rarely obovate to rounded, smooth, green and slightly spinose. Flower buds reddish with yellow tips. Florets reddish orange, changing to red on fading. Maturity late.

II. Bracts spinose, outer lanceolate, inner felted and white

(*a*) *Florets white*

Type 50.—Habit erect. Plants intermediate in height, about 125 cm. high. Leaves dark green, incised, 20-26 × 4·5-5·5. Bracts lanceolate, felted and white, and moderately spinose with short spines. Flower buds white. Florets white, changing to dirty white on fading. Maturity intermediate.

(*b*) *Florets yellow, turning to brownish yellow on fading*

Type 9.—Habit erect. Plants tall, about 145 cm. high. Leaves dark green, dentate to incised. Bracts lanceolate, with a few short spines, felted and white. Maturity late.

Type 51.—Habit spreading. Plants short, about 100 cm. high. Leaves green and broadly dentate, 20-23·5 × 4·5-5·5. Bracts lanceolate, long, felted and white, and slightly spinose. Flower buds pale yellow. Florets yellow, turning to brownish yellow on fading. Maturity early.

Type 52.—Similar to Type 51 in habit, height, flower buds, florets and maturity. Leaves broadly serrate, 16-18 × 4·5-5. Bracts, however, are distinctly shorter and narrower than in Type 51, though lanceolate, felted and white, and slightly spinose as in Type 51.

(*c*) *Florets yellow, turning to red on fading*

Type 15.—Plants short, about 100 cm. high. Maturity intermediate.

Type 16.—Plants intermediate in height, about 110 cm. high. Maturity intermediate.

Type 53.—Habit erect. Plants intermediate in height, about 120 cm. high. Leaves light green, incised, 23-28 × 5-7·5 cm. Bracts lanceolate, felted and white, and spinose with apical spine prominent. Flower buds yellow with no red dot at the apex. Florets yellow, turning to orange red on fading. Maturity late.

Type 54.—Habit spreading. Plants intermediate in height, about 110 cm. high. Leaves green and incised, 17-20 × 4·5-5 cm. Bracts lanceolate to elliptical, felted and white, and spinose. Flower buds yellow with red dot at the apex. Florets yellow, turning to red on fading. Maturity intermediate.

(*d*) *Florets deep red*

Type 55.—Habit erect. Plants intermediate in height, about 115 cm. high. Leaves dark green, incised, 20-30 × 6-8 cm. Bracts lanceolate to elliptical, felted and white, and with a few short spines. Flower buds deep red with yellow apical dot. Florets orange red, fading to deep red. Maturity late.

III. Bracts spinose, outer obovate to rounded, inner smooth and green

(*a*) *Florets yellow, turning to red on fading*

Type 19.—Plants tall, about 165 cm. in height. Bracts obovate to rounded, smooth and green, with a few short spines. Maturity late.

Type 22.—Habit erect. Plants tall, height a little over 130 cm. Leaves serrate to dentate. Maturity early.

Type 56.—Habit spreading. Plants intermediate in height, about 115 cm. high. Leaves green, serrate, but not spinose, 16-22 × 5-6 cm. Bracts obovate to rounded, spinose, smooth and green. Flower buds yellow with no red dot at the apex. Florets yellow, turning to red on fading. Maturity intermediate.

Type 57.—Habit spreading. Plants short, about 100 cm. in height. Leaves green, serrate but not spinose, 13-15 × 3-4 cm. Bracts obovate to rounded, smooth and green, and with very short spines. Flower buds, florets and maturity as in Type 56.

(*b*) *Florets deep red*

Type 24.—Plants tall, about 150 cm. in height. Bracts obovate to rounded. Maturity intermediate.

Type 58.—Habit spreading. Plants intermediate in height, about 110 cm. high. Leaves dark green, incised, 14-16 × 4-4·5 cm. Bracts obovate to rounded, smooth and green and slightly spinose. Inner bracts very small. Flower buds deep red with a yellow apical point. Florets orange red, turning to deep red. Maturity intermediate.

IV. Bracts spinose, outer obovate to rounded, inner felted and white

(*a*) *Florets white*

Type 59.—Habit erect. Plants tall, about 145 cm. in height. Leaves light green, broadly serrate, 14-19 × 3·5-5·5 cm. Bracts obovate to rounded, felted and white, and slightly spinose. Flower buds and florets white, changing to dirty white. Maturity early.

(*b*) *Florets yellow, turning to brownish yellow on fading*

Type 8.—Plants intermediate in height, about 115 cm. high. Bracts obovate to rounded, slightly spinose. Maturity intermediate.

(*c*) *Florets yellow, turning to red on fading*

Type 10.—Plants tall, about 100 cm. high. Leaves broadly serrate at the upper end and slightly incised at the lower. Bracts quite broad, obovate to rounded, slightly spinose. Maturity late.

Type 12.—Plants intermediate in height, about 120 cm. high. Leaves green, serrate and slightly incised at places towards the base. Bracts obovate to rounded, slightly spinose. Inner bracts very short. Maturity intermediate.

Type 13.—Habit erect. Plants tall, about 155 cm. in height. Leaves light green, dentate towards the top and incised towards the base. Maturity late.

Type 14.—Plants tall, about 150 cm. high. Bracts obovate to rounded or elliptical to rounded, slightly spinose. Flower buds deep yellow with a red dot at the apex. Maturity intermediate.

Type 60.—Habit erect. Plants intermediate in height, about 110 cm. high. Leaves dark green, serrate, 18-25 × 6-7 cm. Bracts obovate to rounded, very large in size, felted and white, and with a few short spines. Flower buds yellow with no red dot at the apex. Florets yellow, turning to red on fading. Maturity intermediate.

V. Bracts spineless, outer lanceolate, inner smooth and green

(*a*) *Florets yellow, turning to red on fading*

Type 29.—Plants intermediate in height, about 105 cm. high. Flower buds deep orange yellow, with an apical red dot absent or very faint, but with distinct red streaks or red splashing on the sides. Maturity early.

Type 30.—Plants intermediate in height, about 125 cm. high. Leaves serrate. Flower buds deep orange yellow with an apical red dot very faint or absent. Maturity intermediate.

Type 31.—Plants short, about 95 cm. in height. Flower buds deep orange yellow with an apical red dot very faint or absent, but with red streaks on the sides. Similar to Type 29, except in the habit and height. Maturity intermediate.

Type 32.—Plants short, about 100 cm. high. Flower buds orange yellow with distinct red streaks on the sides. Maturity early.

Type 33.—Plants short, about 100 cm. in height. Flower buds orange yellow with distinct red streaks. Maturity early.

Type 34.—Plants short, about 100 cm. in height. Flower buds deep orange yellow, with distinct red streaks. Maturity intermediate.

VI. Bracts spineless, obovate to rounded, inner felted and white

(*a*) *Florets white*

Type 61.—Habit erect. Plants intermediate in height, about 120 cm. high. Leaves dark green, incised, 16-19 × 4·5-6 cm. Bracts obovate to rounded, felted and white, comparatively very few in number and very small in size, and spineless. Flower buds and florets white, turning to dirty white on fading. Maturity early.

(*b*) *Florets yellow, turning to red on fading*

Type 11.—Plants tall, about 145 cm. high. Leaves dark green, serrate. Bracts obovate to rounded and spineless. Maturity intermediate.

Type 62.—Habit erect. Plants intermediate in height, about 120 cm. high. Leaves green, incised, 25-30×6-7·5 cm. Bracts elliptical or obovate to rounded, felted and white, and spineless. Flower buds yellow, with no apical red dot. Florets yellow, turning to orange red on fading. Maturity late.

(c) Florets deep red

Type 17.—Plants tall, about 165 cm. high. Bracts obovate to rounded. Maturity intermediate.

Type 63.—Habit spreading. Plants intermediate in height, about 110 cm. high. Leaves green, incised, 20-25 × 5-6 cm. Bracts obovate to rounded, felted and white, spineless. Flower buds deep red, with yellow tips. Florets orange red, turning to deep red on fading. Maturity intermediate.

Summary

1. The work of the previous investigators on Indian safflower (*Carthamus tinctorius* L.) has been reviewed.

2. The crop as a whole has been classified into types on the basis of distinctive characters.

3. A key to the types is worked out.

4. Twenty-nine new types have been added with short diagnostic notes on each.

REFERENCES

Howard, A. ; Howard, G. L. C. and Khan, A. R. (1915). *Mem. Dept. Agric. Ind., Bot. Ser.* **7**, 237-255.

Khan, A. R. (1929). *Mem. Dept. Agric. Ind., Bot. Ser.* **18**, 81-87.

INFLUENCE OF STEEPING IN SOLUTIONS OF VARYING HYDROGEN-ION CONCENTRATIONS ON THE GERMINATION AND EARLY GROWTH OF CANES

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Introduction

The question of increasing the growth and sucrose content of canes has been engaging the attention of scientific agriculturists since a long time and a good many measures have been advocated towards the initiation of a profitable sugarcane cultivation. One of the most common practices in this direction is the pre-soaking of canes in water under completely submerged conditions for varying durations of time which not unoften results in increased and rapid germination of the buds followed by an early establishment of the plant.

The experiments performed during the previous years on the physiology and chemistry of sugarcane at this Experiment Station gave encouraging results in this regard, and conclusive evidence was forthcoming in favour of the possibilities of increasing the sucrose content and growth of canes. Among the many treatments which accelerate germination and growth, the soaking of canes in solutions of varying hydrogen-ion concentrations has been one. To the elucidation of the results obtained in this connection the present paper is mainly devoted.

The cane variety used for experimentation is the well-known Co. 331 which has been fully adapted to the conditions of the experimental farms at this Experiment

Station for a number of years. The choice fell on this variety of cane as it provided a tall, erect stem of more or less uniform diameter having long internodes. Canes of the same age and developmental stage are selected and discarded to the extent of one-third each way while the remaining one-third middle portion of more or less uniform sugar content is selected for experimentation. From this are cut setts of uniform diameters and fresh weight, eight inches in length with a single eye in the middle. Special care is taken to discard injured setts and eyes, as well as to standardise as far as possible the size and condition of the buds so that any difference on this account might not vitiate subsequent analysis of the data.

The variation in the pH value is brought about by the use of Merck's normal hydrochloric acid and caustic soda solutions which are diluted to yield the desired pH. Following are the concentrations used with their respective pH values :—

Hydrochloric acid		Sodium hydroxide	
N/100	pH 2	*N*/100	pH 12
N/10,000	pH 4	*N*/10,000	pH 10
N/1,000,000	pH 6	*N*/1,000,000	pH 8

For varying the hydrogen-ion concentration buffer solutions could not be used, as all of them are composed of a number of different chemicals. In consequence it becomes difficult to judge whether the observed effect is due to the alteration in the hydrogen-ion concentration or to the changed concentration of the salts used. As the reaction alters after a certain period of contact between the solutions and cane setts, the liquid is frequently changed. The temperature during steeping is maintained exactly at 15°C.

After the allotted period of twenty-four, forty-eight and ninety-six hours the setts are taken out of the solution, thoroughly rinsed with tap water and allowed to grow in earthenware vessels after Venkatraman [1924] with necessary modifications, the nutrient media used being water. The control sett direct from the field is also allowed to grow side by side in the same manner.

The germination rate of both sett roots and buds as well as their sugar content are recorded. The germinated seedlings are harvested after a period of two-and-half months after sowing and their final dry weight is determined. An average of a large number of canes from each pH is used to allow the biometrical treatment of results. Sugar is determined at three distinct stages in the life-cycle (*i*) when the sett roots sprout, (*ii*) when the buds germinate, and (*iii*) at harvest. A random sample of ten setts is taken out, 1½ inches from both the ends rejected and the rest crushed to get the juice. This is done in duplicate and in setts where the difference between the two samples is significant, analysis is extended to fresh ones.

The modified picric acid method is adopted for the determination of the reducing sugars and sucrose [Willaman and Davison, 1924]. Calculation is made according to the corrected table given by these authors.

Experimental results

A. Germination energy of sett roots and buds

Three criteria have been adopted for determining the best germination energy. They are (*a*) early start, (*b*) early attainment of a high maximum and (*c*) early completion of the process. A study of the curves (Figs. 1 and 2) representing the percentage of setts showing germination on the various dates indicates that the differently trea ted setts differ in all these respects.

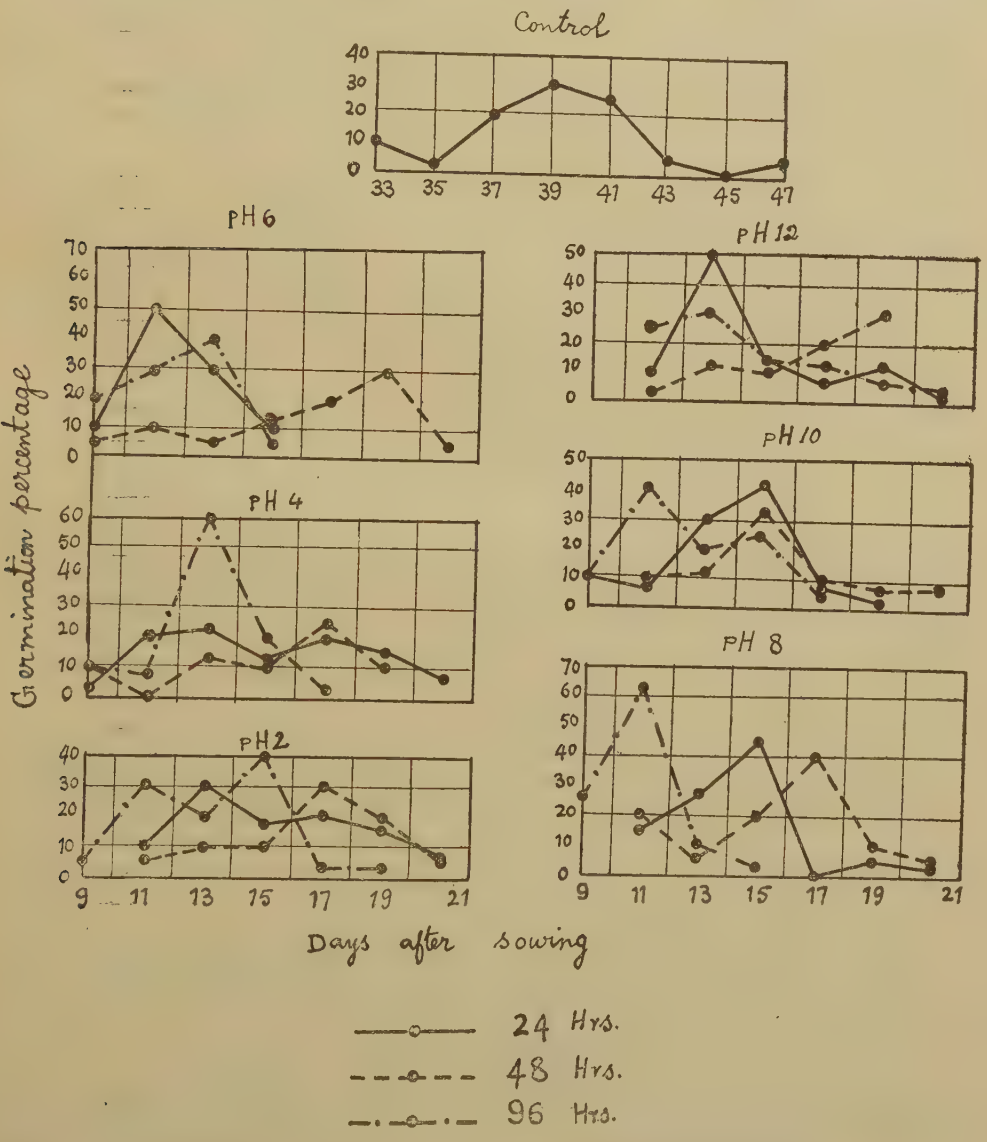

Fig. 1. The germination energy of sett roots in the differently treated setts.

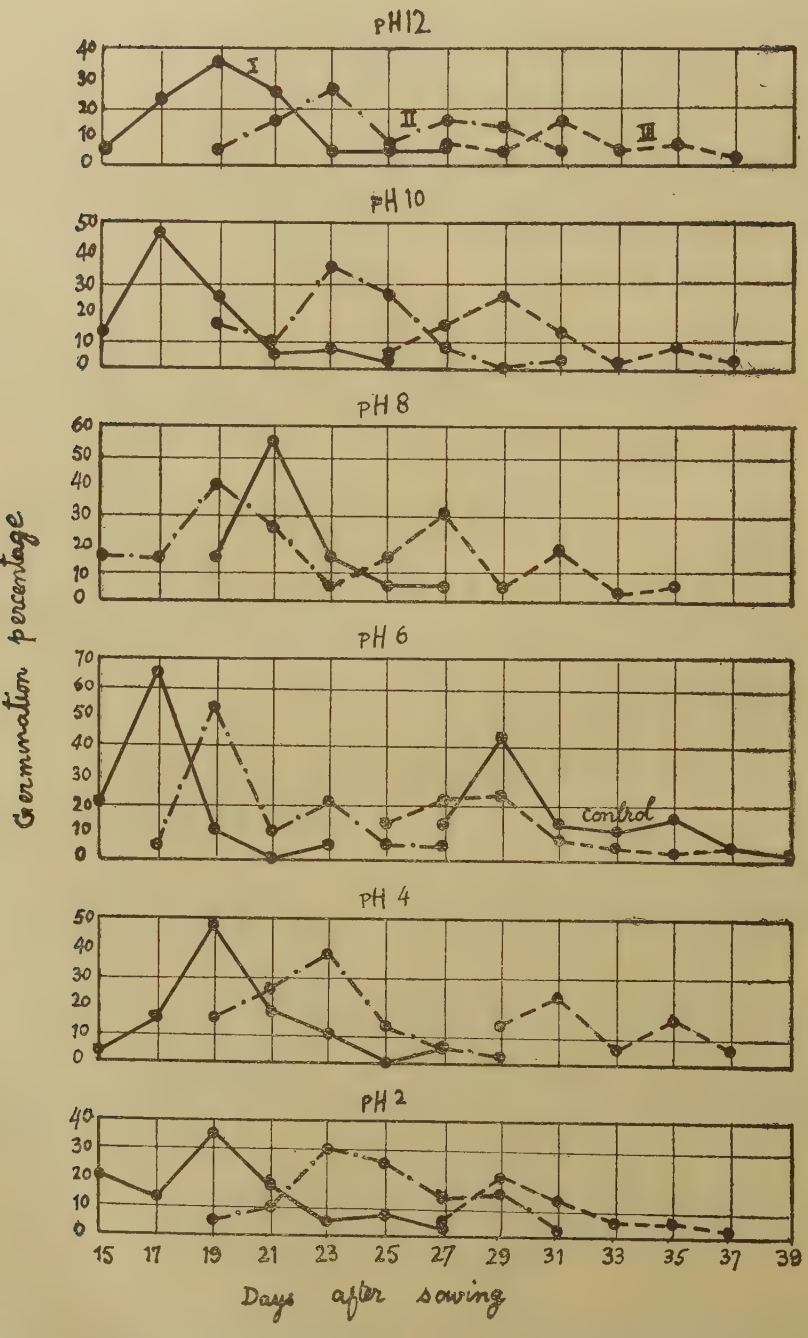

Fig. 2. Germination energy of buds in the differently treated setts. I 24 hours. II 48 hours. III 96 hours.

Germination of sett roots in some of the treated canes starts nine days after sowing and extends in certain cases up to the twenty-first day. A comparative study of the rate of germination in the light of the above-mentioned criterion for the different periods of treatment, *i.e.*, twenty-four hours, forty-eight hours and ninety-six hours indicates that the canes treated for forty-eight hours germinate earliest on the ninth day in five hydrogen-ion concentrations out of six, the exception being at the extreme alkaline side. Next to this come setts treated for twenty-four hours. The superiority of forty-eight hour treatment is also indicated by the early attainment of a high maximum. Setts treated at pH 8 and 10 attain the maximum on the third day after the start; the former comes to a value of 62·5 per cent, the highest record on a single day, while the value for the latter is only 40 per cent. Maximum on the 5th day after the start is shown by the setts treated at pH 4, 6 and 12, the values attained being 62·5, 40, and 30 per cent respectively. From this point of view also ninety-six hour treatment comes last with the highest maximum of 32·5 per cent in pH 8. As to the rapidity of finishing the process, the twenty-four hour and ninety-six hour periods decidedly lag behind the forty-eight hour, as in the majority of the cases the process comes to an end as early as the thirteenth day.

As to the comparative effect of the different hydrogen-ion concentrations the best germination energy is found to be displayed in all the three periods by the canes treated in hydrogen-ion concentrations near about neutrality. Thus for the forty-eight hour period the highest maximum of 62·5 per cent is shown by pH 8. The same for twenty-four hour period is noticed at pH 6.

A cent per cent germination occurs in the twenty-four and forty-eight hour periods. The germination percentage in the ninety-six hour period is low in comparison to the previous ones which clearly indicates the harmful effect of this prolonged period of treatment. Out of the total canes in each case in pH 2—80 per cent, pH 4—67·5 per cent, pH 6—87·5 per cent, pH 8—97·5 per cent, and pH 12—77 5 per cent showed germination.

The control starts with a value of four as late as thirty-four days after sowing and its germination energy is also poor with a maximum of only thirty per cent towards the middle. It is interesting to note in this connection that germination of sett roots in all the treated ones occurs twenty-four days prior to the control.

In the case of buds the germination starts one week after the sprouting of sett roots. Unlike the sett roots the best germination energy is displayed by setts treated for twenty-four hours. In this period out of six hydrogen-ion concentrations five indicate sprouting on the seventeenth day. In the forty-eight hour period of treatment only pH 6 sprouts on the third day while the rest are delayed up to the nineteenth (pH 8) and the twenty-first days. The bud germination in ninety-six hour period of treatment closely corresponds to the sett root germination and indicates the deleterious effect of this prolonged period of soaking. The germination starts very late and in certain cases occurs

only two days prior to the completion of this process in the setts of the previous treatments. The maximum in twenty-four hour period comes earliest and occurs on the nineteenth day at pH 6 and 10 with values of 70 and 47·5 per cent respectively. In ninety-six hour period the maximum is extremely low, the highest being in pH 8 with a value of 32·5 per cent only. As to the rapidity of finishing the process, the forty-eight hour and ninety-six hour periods decidedly lag behind. Out of six cases, in five the twenty-four hour period completes earlier than the forty-eight hour. The deleterious effect of the ninety-six hour period of treatment is also shown by the low percentage of total germination. Both the extremes are harmful but the extreme alkaline side is more deleterious in effect than the extreme acidic side. This becomes more clear when the total number of setts germinated at each treatment is noted. They are as follows :—pH 2—50 per cent, pH 4—60 per cent, pH 6—75 per cent, pH 8—80 per cent, pH 10—62·5 per cent and pH 12—42·5 per cent. Best results are found to occur at pH 6 and 8 and are similar to those noted for roots.

The control gives a cent per cent germination. Sprouting begins on the thirtieth day and a maximum of 42·5 per cent is reached two days later. The process stops on the forty-second day.

B. Sugar content of the mother sett

The curves for sucrose and reducing sugars (Fig. 3) indicate that in all the three periods the sucrose value falls from first to the last stage. The widest fall is noticed in the setts treated for twenty-four hours and is followed by those treated for forty-eight and ninety-six hours, respectively. As to the relative degree of the sucrose conversion among the variously treated setts a close examination of the curves will reveal that in the majority of cases they possess a depression in the middle, that is, near about the neutral point. Except the first stage in ninety-six hour period the alkaline extreme shows a greater presence of sucrose than the extreme acidic side.

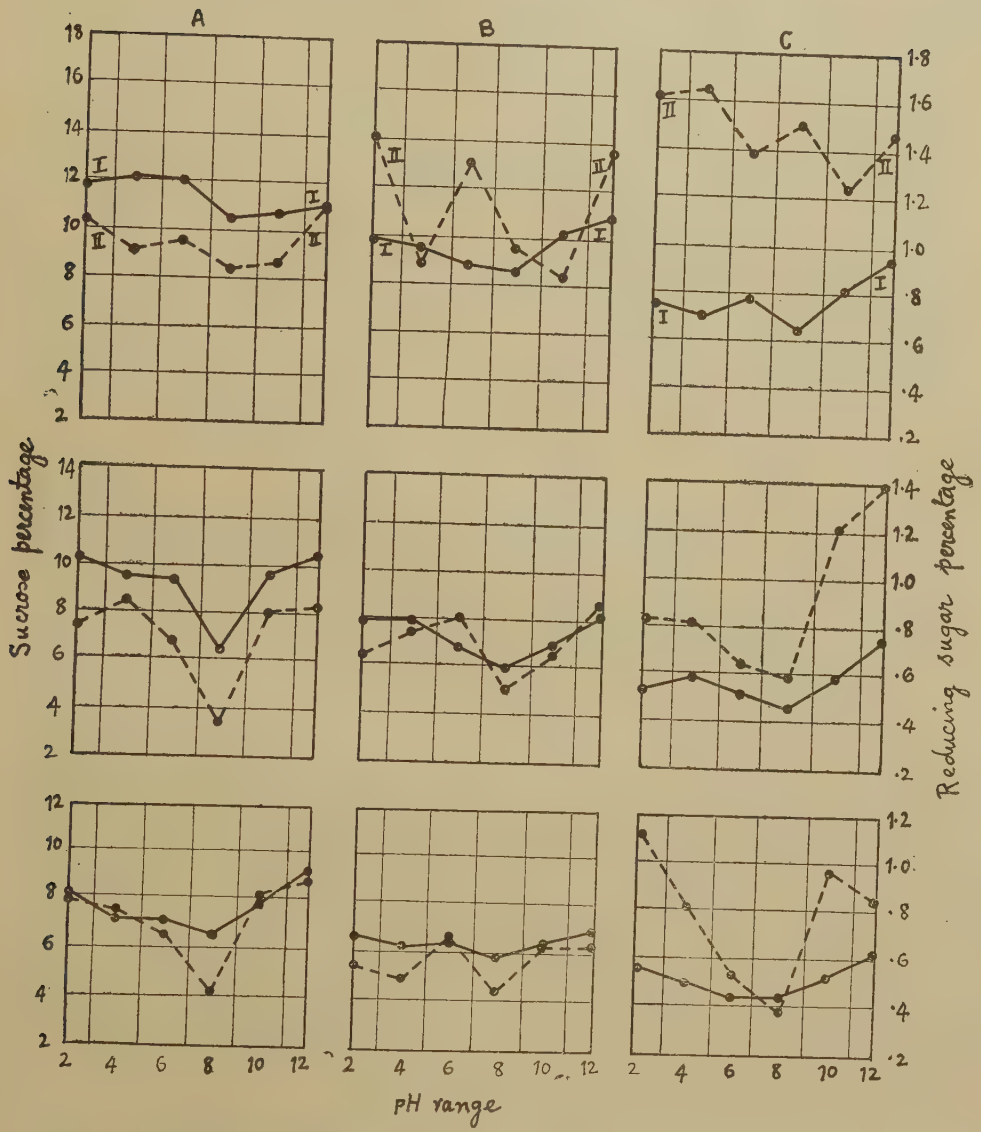

Fig. 3. The values of sucrose and reducing sugar contents of the differently treated setts during A—bud germination stage. B—sett-root germination stage and C—harvest stage. I Sucrose. II Reducing sugar. Top row—96 hrs. treatment; middle row—48 hrs. treatment; and bottom row—24 hrs. treatment.

The values obtained for glucose in majority of the cases run parallel to the sucrose and shows a minimum value where there is less sucrose. As to their production there is not much difference between twenty-four hour and forty-eight hour periods but the ninety-six hour period stands distinctly from them.

Here for all the stages the reducing sugars show a clear accumulation. A high accumulation of glucose is also noted in the third stage of all the different periods of treatment in both extreme acid and alkaline sides.

The rate of conversion of sucrose is more rapid when the period of treatment is short. There is not much regularity about the glucose but a study of the longer-treated setts (96 hours) indicates that a higher accumulation of this substance may be due to a long period of treatment.

The sucrose consumption is more in setts treated with neutral solutions than the setts treated with either higher or lower pH. The reducing sugars also, to a certain extent, run parallel to the sucrose and there seems to be a relatively high consumption of this substance in setts treated in solution which were near about neutrality. In treatments ranging over a very long period a greater accumulation of sugar is noticed towards the extreme acidic and alkaline sides.

C. Production of dry matter

Roots.—The beneficial effect of soaking becomes quite evident when we study the dry matter production. A reference to Fig. 4 indicates that except pH 4 of ninety-six hour treatment all others give a better dry matter output than the control. Of the three periods, forty-eight hour series show a marked superiority to the rest, while the ninety-six hour sett occupies the lowest position as usual. The dry weight increases from the extreme acid side, attains a maximum at pH 8 and then comes down up to the end. A fall is noticed at pH 6 of the shorter period. The nature of the curve in twenty-four hour period is different from others. Here the readings start with a low value, increase up to pH 6, after which they remain more or less constant up to pH 12. The decrease in the output of dry matter towards the acid side does not appear to be due to an over-dose as a prolongation of this period to forty-eight hours appears to be beneficial as indicated by an increase in dry weight.

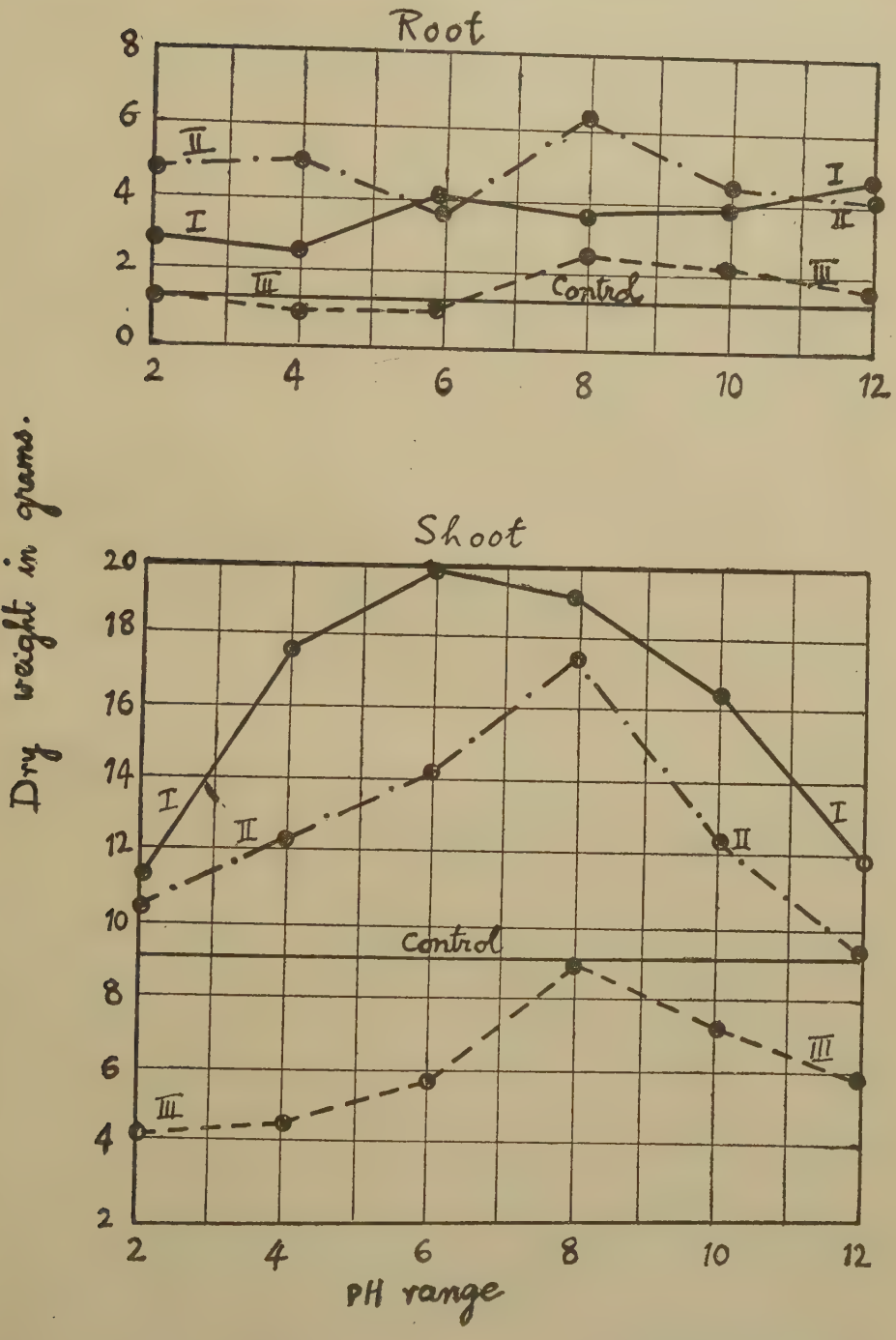

Fig. 4. Dry matter output of the shoot and root obtained from differently treated setts.

I 24 hours. II 48 hours. III 96 hours.

It is interesting to note that maximum dry matter production in all the three periods is continued to pH 8, (48 and 96 hours) and pH 6, (24 hours)—the hydrogen-ion concentrations which were found to give a better germination energy.

Buds.—The dry matter output of buds is found to decrease with the increase in the period of treatment. Thus all the setts treated for ninety-six hours give the lowest dry matter which is even lower than the control. In the case of the buds also the readings start from a low value on the acidic side, attain a maximum at pH 8 in forty-eight and ninety-six hours and at pH 6 in twenty-four hours and gradually fall down towards the alkaline side. The increase in dry matter over the control due to stimulation is significant. At pH 6 of twenty-four hours which gives the best growth of all the treated setts the dry matter output is $19 \cdot 82 \pm 0 \cdot 231$ grm., while that of the control is only $9 \cdot 24 \pm 0 \cdot 104$ grm. The increase over the control is 114·8 per cent.

Discussion

The relation of germination vigour to the production of dry matter

A higher dry matter output is found to be associated in majority of the cases with a higher germination energy. For example the setts which are treated for a period of twenty-four hours give a lower dry matter output of roots than the setts treated for forty-eight hours. As to germination energy, the former gives a maximum in majority of cases four days later than the forty-eight hour treatment. The pitch of the maximum is much lower in the case of twenty-four hour treated setts than in the forty-eight hour treated ones to which reference has already been made in the previous pages. Ninety-six hour treated setts give the lowest dry matter output and a poor germination.

The effect of germination energy on dry matter output is found to be evident even when the setts treated at various pH values are compared among themselves. For example pH 8 in forty-eight hour period possesses the best germination energy as revealed by a value as high as 62·5 per cent attained two days after germination. In the case of twenty-four hours also the best germination energy is noted in pH 6, 8, 10 and 12 all of which give nearly equal dry matter production. In the case of ninety-six hours where the majority of the curves are of flat nature a definite maximum is shown at pH 8 which also gives the highest dry weight output.

The same appears to be true to an equal extent of bud germination. As regards the dry matter output in this case, twenty-four hour period in all its pH ranges is found to have better performance than forty-eight hour which, in its turn, is better than the ninety-six hour. As far as germination is concerned excepting pH 8, in all the cases the twenty-four hour comes prior to forty-eight

hour higher duration treatment. In ninety-six hour period the maxima are invariably late when compared with shorter periods and also the starting of germination is nearly a week behind as already mentioned. Thus these facts seem to indicate that germination energy and subsequent growth, as represented by dry weight, go hand in hand.

Attention may be drawn to the observations made by Tincker [1925] in this connection. From a synopsis of the experiments described by the author it appears that a definite correlation does exist between the vigour of germination and the rate of subsequent growth in the case of oats. Such relationship has also been demonstrated by Kondo for rice [1923] in conformity with our own results discussed above.

Increment in the dry matter output due to treatment

As a result of pre-soaking treatment there is an apparent increase of 114·8 per cent in dry matter of the shoot over the control, and this occurs in the case of setts treated in pH 6 in twenty-four hour period of soaking which has shown the best growth among all the other treatments. The difference has been found to be statistically significant. This result is highly encouraging and if this can be maintained under field conditions without any appreciable decrease in the sucrose content and other desirable qualities, it will constitute a substantial advance in the sugarcane industry.

Similar increased growth due to chemical treatment has been observed by many other workers. Gleisberg [1924] noticed that the vegetative growth of radish was increased up to 364 per cent when the seeds were treated in fifteen per cent magnesium chloride and magnesium sulphate. He also noted a doubling of yield in seeds treated with distilled water. Extensive work on the effect of chemicals upon hastening germination and increasing the yield has been carried out by Denny [1926 ; 1, 2] who found best results from treatments with vapour of ethylene chlorhydrin and solutions of sodium and potassium thiocyanate. The treated tubers showed cent per cent germination and in a period of two months the plants were two feet high with a formation of tubers, while the control ones did not appear above the ground. On the other hand Smith [1930] working with wheat came to the conclusion that none of the treatments used by this author proved to be highly stimulative to growth. The failure in getting an increased growth is most probably due to the fact that the author confined himself to a single treatment and a single concentration with each of the chemicals. The works of Denny [1926 ; 1, 2] and his co-workers have clearly indicated that there are particular optimal periods and concentrations of treatment for the different crops worked upon. The optimum concentration has also been found to vary in the case of different varieties of the same crop.

Relation of sucrose and reducing sugars present in the mother sett to growth

An interesting point in the observation so far recorded is that the maximum growth of buds and sett roots generally occurs in setts which have been treated for the various periods in solutions the reactions of which are maintained slightly above or below neutrality. In order to understand whether the conversion of sucrose to glucose has got anything to do with increased growth or not, it is necessary to go back to those data which have already been referred to (Fig. 3). A study of the glucose and sucrose readings seem to indicate that wherever there is higher growth, both reducing sugars and sucrose values are relatively low. For example the sucrose values of twenty-four hours during all the three periods of analysis are low when compared to forty-eight hours. Forty-eight hour in its turn shows readings lower than those of ninety-six hours where minimum growth occurs. When an inter-comparison of setts at various pH values for the same period is made, the minimum sucrose is found to occur in setts treated with pH 8 where the growth is also the highest. The low sucrose content in case of setts where high growth prevails can be explained on the basis that at such an early stage when the offspring are not yet established independently, it is the conversion of sucrose which supplies the respiring and tissue-forming materials. Hence increased growth requires a greater amount of these growth materials and an equal amount of drain on the reserve sucrose material. This naturally seems to be the reason for the low sucrose value obtained in such vigorously growing canes. It is interesting to note that the value of glucose is relatively low where a consumption of sucrose exists. This seems to be quite natural as the reducing sugar value, that is obtained during any period of analysis, is essentially the difference between the amount of it formed from sucrose and the amount used up. High rate of growth leads to high consumption of these reducing sugars and most probably for this reason the balance is low.

The storage material being mostly sucrose in sugarcane it may be expected that a greater conversion of sucrose to reducing sugars which forms the suitable substrate for the germinating buds and sett roots should occur in the setts which are soaked in solutions of more acidic nature and that they should give earlier and better growth as compared to control, but on the contrary the best growth is not seen in such treatments.

In order to understand whether the sucrose conversion is brought about by some change in the reaction of the juice of the mother sett, a reference is made to a record of the hydrogen-ion concentration of the differently-treated setts. These records are taken only for the first period of analysis by the quinhydrone electrode. A perusal of Table I clearly reveals that the hydrogen-ion concentration varies from 5·412 to 5·583 and that there is no regularity as to their order and arrangement in relation to high sucrose conversion.

TABLE I

pH value of the sap extracted from the mother setts at the sett-root germination stage

Setts treated at pH	24 hours	48 hours	96 hours
2	5·471	5·518	5·496
4	5·498	5·480	5·412
6	5·467	5·583	5·483
8	5·516	5·502	5·559
10	5·441	5·498	5·442
12	5·492	5·529	5·537
	Control	5·465	

In pH 6 and 8 of twenty-four hours, where growth and sucrose conversion are at the maximum, the pH values are 5·467 and 5·516, but these seem to be almost similar to the pH value of the setts treated at pH 2 where the growth and sucrose conversions are at minimum. The same seems to be the case with forty-eight hour and ninety-six hour periods also. It appears that the reaction of the sap has not much to do with the increased growth and sucrose conversion.

The exact mechanism by which the enhancement of growth occurs still awaits investigation and it may be found in other aspects of the metabolism of the stimulated individuals.

SUMMARY AND CONCLUSIONS

The present investigation is an attempt to study the effect of pre-soaking of sugarcane in solutions of different hydrogen-ion concentrations upon germination and growth of seedlings. The following observations are recorded :—(*i*) germination energy of sett roots and buds, (*ii*) march of glucose and sucrose contents in the mother setts, (*iii*) the hydrogen-ion concentration of the juice and (*iv*) the dry-matter output of both sett roots and buds when harvested two and a half months after sowing.

The differently-treated setts are found to vary both as regards germination energy and dry-matter output. There seems to exist a positive correlation between the two. The maximum growth is found to occur at pH 6-8. The best result is obtained for the sett-root growth in forty-eight hour treatment, while that

for the growth of shoot is exhibited by the setts treated for a period of twenty-four hours. Thus the sett roots and buds are found to be stimulated differently by the treatment. All the treatments, except that of ninety-six hours, have shown an increase in the production of dry matter over the control. In pH 6 of twenty-four hours duration the increase is up to 114·8 per cent.

The sugar-analysis records indicate a greater conversion of sucrose into glucose and also a greater consumption of the latter under treatments which give the best growth.

Contrary to expectation this greater conversion occurs near about the neutral side of the reaction. The records of the hydrogen-ion concentration indicate that the difference in the behaviour as to the sucrose conversion in the differently-treated setts cannot be explained on this basis. No correlation is found to exist between the two. It is suggested that the exact cause of stimulation should be searched in other aspects of the metabolism of the treated setts.

The present investigation opens up an apparently new field of enquiry for sugarcane and further investigation may be in a position to furnish some treatment which may be of direct benefit to the cultivator in getting an increased yield.

REFERENCES

Denny, F. F. (1926,1). *Amer. J. Bot.* **13**, 118-125.

———————— (1926,2). *Ibid* **13**, 386-396.

Gleisberg, W. (1924). *Deut. obst. u. gemusebau Ztg. Woch. Ausg.* **70**, 4, p. 28 (*Exp. Stn. Rec.* **50** No. 7,643, 1924).

Harrington, G. T. (1923). *J. Agric. Res.* **13**, 2, 79-100.

Jones, M. G. and Tincker, M. A. H. (1926). *Ann. App. Biol.* **13**, 4, 535-559.

Kondo, M. (1923). *O'Hara. Inst. Bull.* **Bd. II**, Heft 3, 291.

Smith, D. C. and Bressman, E. N. (1930). *J. Agric. Res.* **40**, 25-36.

Tincker, M. A. H. (1925). *Ann. App. Biol.* **12**, 440-469.

Venkatraman, T. S. amd Thomas, R. (1924). *Agrc. J. Ind.* **14**, 509-514.

Willaman, J. J. and Davison, F. R. (1924). *J. Agric. Res.* **28**, 5.

A NOTE ON PHOTO-PERIODISM IN SESAMUM

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(With Plates XXXI-XXXIII)

Introduction

The Burmese have recognised for a long time that there are two distinct classes of sesamum which they distinguish by the names *Hnanyin* and *Hnangyi*, indicating that the former class are for growing during the monsoon and the latter class during the cold weather. In Burma it has been customary to designate these two classes " early " and " late " in English irrespective of what the life-period may be [Rhind and Ba Thein, 1932]. The " early " class are usually sown from April to the end of June and are harvested in August or September though they can be sown as late as October. If, however, they are sown late, the growth is curtailed and yield suffers. The " lates " are sown from September to October and harvested in December or January. If they are sown in the " early " season, growth is rank and coarse but flowering is either entirely suppressed or the flowers are abnormal and fail to set fruits.

Rhind and Ba Thein [1932] have shown that the " late " character appears to be a simple dominant over " early ".

Effect of sowing date on " late " sesamum

In 1934 two types of " late " sesamum were sown in field plots at Mandalay (Lat. 22°N.) at weekly intervals commencing on 15th June. The types were *Boktaung L 31-33*, a long-lived type, fully branched, with four-locular, solitary capsules and brown seed, and *Thadunbyu L 31-12*, a short-lived, unbranched type with four-locular, solitary capsules and white seed. The results are summarised in Tables I and II.

Table I

Effect of sowing Boktaung L 31-33 *on various dates*

Sowing date	Date of 1st gland	Date of 1st flower	Fruit	Sepaloid plants per cent	Total No. of plants	Hours of day light at sowing date	Notes
I 15th June 1934	12th Sep. 1934	*Nil*	*Nil*	32	147	13·28	See (1) below.
II 22nd June 1934	,,	27th Sept. 1934	Few	30	131	13·28	Do.
III 29th June 1934	,,	27th Sep. 1934	Few	24	166	13·28	See (2) below.
IV 6th July 1934	,,	12th Oct. 1934	Many	24	154	13·26	See (3) below.
V 13th July 1934	27th Sep. 1934	,,	Many	16	233	13·26	Do.
VI 20th July 1934	...	,,	Many	10	282	13·18	
VII 27th July 1934	...	,,	Many	4	192	13·14	See (4) below.
VIII 3rd Aug. 1934	6th Oct. 1934	,,	Many	1·5	269	13·08	See (5) below.
IX 10th Aug. 1934	,,	...	Many	9·5	238	13·02	See (6) below.
X 17th Aug. 1934	,,	12th Oct. 1934	Many	1·1	260	12·56	See (7) below.
XI 24th Aug. 1934	12th Oct. 1934	...	Many	0·0	...	12·48	Do.
XII 31st Aug. 1934	,,	...	Many	0·0	...	12·40	Do.
XIII 7th Sep. 1934	...	...	Many	0·0	...	12·34	Do.
XIV 14th Sep. 1934	...	...	Many	0·0	...	12·26	Do.

(1) The general appearance of this plot on 27th September (104 days from sowing) was tall, rank plants, with little branching below two feet and much branching in the uppermost foot (top-branching, Plate XXXI, fig. 1). The upper small branches were bearing flowers but setting very few capsules. Plants which showed sepaloid growth a month ago, now bearing apparently normal flowers.

2) These plants also showed top-branching but less pronounced than I and II. There was some sepaloidy but by 27th September (91 days from sowing) a few apparently normal flowers were produced though they failed to set fruits. Some plants ultimately produced normal growth after having shown the sepaloid condition in the early stages.

(3) Typical growth of the "late" class when grown in the "early" season, with profuse, rank growth and top-branching. After having shown the sepaloid condition, flowering and fruiting occurred by the middle of October.

(4) By 12th October plants were flowering freely but set very few fruits. The sepaloid condition occurred in only eight plants out of 192 and these were not badly affected. Ultimately fruiting became almost normal on the upper parts of the plants.

(5) Branching was mostly at the top in the early part of the life-period. Flowering and fruiting finally became about normal.

(6) The growth was nearly normal, only slightly more rank than when this class is sown in its proper season. The plants affected with sepaloidy were all in one group in the plot, 23 out of 238, and the higher percentage in this case cannot be explained.

(7) Normal growth.

FIG. 1. Late variety *Boktaung L31-33*, sown 22nd August, photographed 28th September, showing top-branching. The plant on the right is commencing to bear normal flowers at the top.

FIG. 3. Late variety *Boktaung L31-33*, sown 6th July, photographed 12th September, control (left) and after 70 hours extra darkness.

FIG. 2. Late variety *Boktaung L31-33*, sown 15th June, photographed 11th September. Given 10 to 60 hours extra darkness.

TABLE II

Effect of sowing Thadunbyu L 31-12 *on various dates*

Sowing date	Date of 1st flower	Fruiting	Sepaloid plants per cent	Total No. of plants	Hours of day light at sowing	Notes
I 15th June 1934	12th Sept. 1934	Few	100	...	13·28	See (1) below.
II 22nd June 1934	.....	*Nil*	100	...	13·28	
III 29th June 1934	12th Sept. 1934	*Nil*	99	...	13·28	
IV 6th July 1934	Ditto	Few	98	...	13·26	
V 13th July 1934	Ditto	Few	75	127	13·26	See (2) below.
VI 20th July 1934	Ditto	Few	67	127	13·18	Do.
VII 27th July 1934	14th Sept. 1934	Few	50	80	13·14	
VIII 3rd Aug. 1934	14th Sept. 1934	Few	41·8	189	13·08	
IX 10th Aug. 1934	27th Sept. 1934	Few	41·2	119	13·02	
X 17th Aug. 1934	27th Sept. 1934	Many	35·4	133	12·56	
XI 24th Aug. 1934	27th Sept. 1934	Many	11·1	224	12·48	
XII 31st Aug. 1934	6th Oct. 1934	Many	2·8	211	12·40	
XIII 7th Sept. 1934	.....	Many	22·9	227	12·34	See (3) below.
XIV 14th Sept. 1934	.....	Many	21·2	250	12·26	

(1) There is some doubt whether this line is pure. There were scarcely any fruits matured and all plants showed the sepaloid condition.

(2) Practically all plants were sepaloid in the early stages but many recovered and formed a few capsules.

(3) The increase in percentage of sepaloidy in the last two sowings is not understood.

In the case of *Boktaung* the sowings prior to 3rd August developed abnormally with few flowers or axillary glands until late in the season when sparse flowering and fruiting with much phyllomania (sepaloidy) occurred. Sowings after the 3rd August developed normally with good fruiting and little or no sepaloidy. The demarkation between the heavy vegetative growth and normal growth was, of course, not sharp, but 3rd August marked the approximate boundary between normal and abnormal growth. Plants which produced sepaloid growth in the early stages frequently produced normal flowers and fruits later in the season. It is noteworthy that with the exception of the sowing on 10th August there was a continual decline in the percentage of sepaloid plants (recovered plants were recorded as sepaloids). Further, in the sowings of the short-lived variety *Thadunbyu* on 7th and 14th of September there was also a rise in the sepaloid percentage. There may have been some climatic cause, but none could definitely be ascertained.

In the case of *Thadunbyu* there was some indication of impurity and the distinction between the heavy, rank growth of " lates " sown too early and normal growth was not always clear. But it is clear that early sowings lead to excessive vegetative growth and much sepaloidy. Sowings from 10th August onwards gave a large number of normal plants.

EFFECT OF REDUCING THE HOURS OF DAY LIGHT

On the 9th July certain plants selected at random growing in the plots sown on 15th June were covered with large flower-pots from 3-30 P.M. to 6-30 A.M., thus reducing the normal period of daylight by about four hours. The treatment was discontinued on 19th July when a total of forty hours extra darkness had been given. The following effects were noticed :—

19th July.—Varieties *Boktaung* and *Thadunbyu*. Covered plants three inches taller than the uncovered.

26th July.—*Boktaung* : Covered plants three to five inches taller than the uncovered. Bearing axillary glands and flower buds up to 0·25 in. across. Uncovered had no glands or buds.

Thadunbyu : Covered plants up to six inches taller. Axillary glands and buds well formed, the latter up to $\frac{3}{4}$ in. long.

29th July.—*Thadunbyu* : Covered plants in flower. Flowers appear normal. Uncovered not showing buds or axillary glands.

30th July.—*Boktaung* : One covered plant with one flower open. Uncovered show neither buds nor glands.

10th August.—*Thadunbyu* : Covered plants flowering and setting fruits. Flowering slowing up as the effect of the treatment appears to be wearing off.

Boktaung : Covered plants flowering but only one capsule set. No buds on untreated plants of either variety.

17th August.—*Thadunbyu* : Covered plants flowering and fruiting. Some plants sepaloid. Upper leaves lanceolate, entire. Some untreated plants flowering ; no fruits set. A few upper leaves broad, lanceolate but mostly tripartite. Some sepaloid.

Boktaung : Covered plants flowering. One capsule set. Upper leaves lanceolate, entire. None sepaloid. Untreated show no buds or glands. Upper leaves tripartite, serrate.

From these observations it is seen that the small amount of extra darkness given, amounting to about four hours per day, was sufficient in ten days to induce flowering and to bring about the formation of the narrow lanceolate type of leaf usually found on the upper parts of flowering sesamum plants. The treatment was not continued beyond the ten days and the plants later reverted to the rank vegetative type of growth.

In a second experiment on the *Boktaung* variety sown on 6th July varying periods of extra darkness from ten to seventy hours in all were given. Specimens of these treated plants and of the control are shown in Plate XXXI,

figs. 2 and 3. The treatments were commenced on 2nd August and on the 11th September the following notes were made :—

Control.—Very coarse, rank vegetative growth. Leaves large. Stem thick, branched. Minute glands and flower buds discernible on some plants.

Ten hours.—Tall, rank. Upper leaves ovate or ovate-lanceolate, scarcely entire. Glands and very small flower buds formed.

Twenty hours.—Rank growth, tall, branched, stem thick, leaves large, upper leaves broad-lanceolate. Glands and small flower buds formed at apex.

Thirty hours.—Same as twenty hours.

Forty hours.—Plants branched ; growth rather coarse, stem thick, foliage coarse. Glands and flower buds formed at apex but not opened.

Fifty, sixty, seventy hours.—Plants shorter than controls. Branched. Flowering. Some capsules about half developed. Upper leaves lanceolate. Plants have general appearance of growing normally.

The increasing effect of the longer periods of darkness is well shown. The experiment was repeated on the same variety sown on 27th July with the same results.

It is clear that when the " late " class sesamums are grown under long days, they tend to produce excessive vegetative growth while reproduction is suppressed or rendered abnormal. If the days are artificially shortened, flowering is induced and also the other changes, such as gland production and alteration in the shape of the upper leaves.

Effect of lengthening the light-period on " late " sesamum grown under short days

In order to test the above results further, a series of pots was sown on 22nd September with the following four varieties of " late " sesamums and four varieties of " early " sesamums :—

	Pot Nos.
Lates	
Thadunbyu L 31-12	1-19
Chaukluknan L 31-18	20-38
Boktaung L 31-33	39-59
Hnanni-gyi L 31-50	60-78
Earlies	
Shithmyaung E 25-137	79-89
Hnan-net E 27-47	90-102
Thadunbyu E 26-136	103-112
Palestine Northern Plain E 34-72	113-120

The germination was good. There was some trouble with damping-off but one spraying with ½ per cent Bordeaux mixture stopped this. The seedlings were thinned out to two per pot. The pots were arranged in sets of four of each variety in the form of a 4 × 4 Latin square under 75-watt, gas-filled lamps calculated to give an average of 6·7 foot candles at the soil surface. Extra electric light was given from sunset for two, four and six hours to three sets of the " lates " and for four hours to one set of the " earlies ", commencing on 6th October when the plants were fourteen days old. There was a failure of the lights on 9th October due to a short circuit but at no other time. The longest extra dose of light, six hours, is only approximate as the switching off of this series was done by the night watchman, the lamp being on the local street-lighting circuit. It is nevertheless approximately correct. The extra illumination affected both growth and reproduction, which will be dealt with separately.

Growth (' *lates* ').—The effect of extra illumination is to reduce growth in height, the effect increasing as the extra period of electric light is increased (Plates XXXII and XXXIII). The plants under four and six hours extra light did not produce the narrow lanceolate upper leaves but only tri-lobed, serrate leaves. They were paler in colour than the controls.

Measurements of heights were made weekly but only the final measurement made on 12th November need be reproduced here. The average heights then were :—

Control	43·57 cm.
Two hours	28·66 ,,
Four ,, ...	24·78 ,,
Six ,, ...	22·38 ,,

The differences between each treatment and the control are all significant ($P < 0·01$) though inter-treatment differences are not significant. Nevertheless, when the plants were arranged in order of increasing periods of illumination there was, with few exceptions, a steady decrease in height as the time of illumination increased. Inter-varietal differences, though considerable in some cases in the two-hour treatment, were not reliable.

Reproduction (' *lates* ').—The controls commenced to flower on the 23rd October in the case of *Thadunbyu* and *Chauklahnan* (short-lived) varieties and on 5th November in the case of *Boktaung* and *Hnanni-gyi* (long-lived) varieties. Flowering and fruiting proceeded normally ; there was no sepaloidy and the plants were ripe about the 10th December.

Of the treated plants only one variety, *Thadunbyu L 31-12*, flowered. The flowering was irregular and only eleven out of the total twenty-four treated plants flowered. These set four capsules. The flowers appeared on various dates between the 25th October and 10th December. The other three varieties

Fig. 1. Late variety *Thadunbyu L31-12*. From right : control, 2 hours, 4 hours and 6 hours extra light.

Fig. 2. Late variety *Chauklahnan L31-18*. From right : control, 2 hours, 4 hours and 6 hours extra light.

FIG. 1. Late variety *Boktaung L31-33*. From right : control, 2 hours, 4 hours, and 6 hours extra light.

FIG. 2. Late variety *Hnangyi L31-50*. From right : control, 2 hours, 4 hours and 6 hours extra light.

did not produce a single flower and the plants finally died towards the end of December. There were glands and small flower buds developed in a few cases on the two-hour and four-hour sets but they failed to expand.

The effect of artificial long days, even with the low intensity of light employed, was very marked and clearly shows that the *Hnangyi* ("late") class are only capable of normal growth and reproduction under relatively short days. At the latitude of Mandalay the mean time of exposure to light (day light + electric light) for the period from 24th September (date of germination) to the 30th November was

	Hours	Minutes
Controls	11	22
Two hours	13	1
Four hours	14	40
Six hours	16	18

(The extra illumination was given for a total of fifty-six days from 6th October).

The additional one hour 39 minutes given to the two-hour series on an average over the fifty-six days from 6th October to 30th November had a pronounced effect, completely suppressing flowering except in one variety and even in that case greatly curtailing it and permitting only a few fruits to set. The average length of day during the normal "early" season from 15th June to 31st August is thirteen hours eleven minutes and under a day of this length the behaviour of "lates" is quite in accordance with that of short-day plants described by other workers, *e.g.*, Garner and Allard [1920], Tinckler [1925; 1928], Adams [1923] and McClelland [1928]. It may be mentioned that Pusa Types 5, 17, 25, 26, 27, 28, 29 and 30 have been found to be short-day varieties when grown in Burma.

Growth ('*earlies*').—The mean heights of the plants receiving four hours extra electric light was 43·15 cm. and the controls 44·35 cm., the difference being insignificant. Both series grew and fruited normally and produced the usual lanceolate top leaves.

Reproduction ('*earlies*').—The dates of opening of the first flower were considerably delayed by the extra period of illumination. All plants of the same variety did not flower on the same day and the dates given below are those for the majority of the plants of each variety. The Palestine Northern Plains variety in particular was irregular in its flowering :—

	Control	Treated
Shithmyaung E 25-187	18th October	22nd October
Hnan-net E 27-47	22nd ,,	10th November
Thudunbyu E 26-136	20th ,,	31st October
Palestine N. P. E 34-72.	19th-27th Oct.	23rd Oct. to 3rd November

The extra llumination has delayed the opening of the first flower from four to nineteen days, the delay being greatest in the case of the longest lived variety, *Hnan-net*. There was no sepaloidy and the plants fruited normally.

Summary

The so-called " late " sesamums (Burmese *Hnangyi*) are typical short-day plants which only grow and reproduce normally under days of about twelve hours or less. An extension of the light period to thirteen hours causes abnormal growth and suppression of flowering.

The " early " sesamums (Burmese *Hnanyin*) are not restricted to any particular day length and are able to flower and fruit under either long or short days though growth and yield are best under long days.

REFERENCES

Adams, J. (1923). *Ann. Bot.* **37**, 75.

Garner, W. W. and Allard, H. A. (1920). *J. Agric. Res.* **18**, 553.

McClelland, T. B. (1928). *J. Agric. Res.* **37**, 603.

Rhind, D. and Ba Thein (1932). *Ind. J. Agric. Sci.* **3**, 478.

Tinckler, M. A. H. (1925). *Ann. Bot.* **39**, 721.

——————— (1928). *Ann. Bot.* **42**, 101.

LIFE-HISTORIES OF SOME INDIAN THYRIDIDAE (LEPIDOPTERA)

BY

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(Received for publication on 18th May 1935)

(With Plates XXXIV-XXXVI)

Introduction

The family Thyrididae is closely allied to the family Pyralidae, so much so, that even trained entomologists are likely to be misled about the exact identity of the larvae and sometimes of the adults of these two families. The moths of the Thyrididae are also likely to be mistaken for those of the Geometridae. The "Pyralid larva forming galls on the twigs of *Phyllanthus emblica*," referred to by Misra [1919] is most probably the Thyridid larva *Betousa stylophora* Swinh., because so far this is the only species which is known to form galls on this plant at Pusa.

The working out of the life-histories of the species belonging to this family involves special effort and that is probably the reason that the detailed life-history of not a single species was known up till 1925, in which year the writer was successful, after repeated failures, in rearing the adults of one species, *viz.*, *Betousa stylophora* Swinh. and later on, of the other species, *viz.*, *Rhodoneura loceusalis* Wlk. The observations on the life-histories of these two insects, together with brief notes on other species of this family taken from the records in the office of the Imperial Entomologist, are embodied in this paper. A brief account of one of these species was given by Fletcher [1931] at a meeting of the Entomological Society of London in 1930.

As various reasons and other pressing duties have prevented the writer from completing a detailed study of these two species, it has been thought desirable to publish such information as has been collected.

I.—*Betousa stylophora* Swinh. (Plates XXXIV and XXXV; Figs. 1, 2, 3, 4, and 5, 6, 7)

Swinhoe [1895] described this species as *Rhodoneura stylophora*. Hampson [1896] first described it as *Hypolamprus stylophorus* but in 1914 included it under *Betousa* Wlk. on account of the priority of the latter genus.

Phyllanthus emblica (Euphorbiaceae) on which this species forms galls, is of some economic importance in India, its fruit being used as pickles, jam, medicine, etc. Fresh galls are generally formed in the summer months, June to August. They often attain maximum size by the beginning of winter, when they are about 23·1 mm. in length and 10·3 mm. in width. The galls when young, are proportionately much longer than broad (Plate XXXIV, figs. 1, 2). Often the galls are distinct from one another, but sometimes two galls are contiguous, having a narrow constriction in between them.

Some empty galls out of which the moths had emerged were found to be occupied by a species of small, black ants along with its young ones. Similarly once a spider and its eight round creamy-coloured eggs were found in a gall.

The writer has not seen the eggs of *Betousa stylophora* Swinh. but presumably they are laid in early summer. The caterpillars bore their way into the interior of the twigs, the bored portion swells up and in due course develops into a gall.

The caterpillar feeds inside the gall (Plate XXXIV, fig. 1) on the internal woody tissue, and passes out reddish frass through a small hole at one end which is kept covered by a mesh-work of silken threads (Plate XXXIV, fig. 2). The larva is nearly full grown about October, it passes the winter season in the larval stage within the gall and comes out in the beginning of the following summer by enlarging the entrance hole, and prepares a cocoon or pupal chamber on the leaf. A mature gall if half split with a knife, was observed to be soldered up immediately by the caterpillar inside by means of silken threads.

In the Insectary, out of some galls collected in March 1925, the caterpillars began emerging in the last week of April and continued coming out up to the end of May. A full-grown caterpillar (Plate XXXV, fig. 5) measures about 10—11 mm. in length and 2·25—2·5 mm. in breadth across the 3rd or 4th abdominal segment. It is cylindrical, tapering gently in the anterior and posterior regions. The head is darkish brown and measures 1·3 mm. across the epicrania and above the ocellar region. The epicranial suture is fine and almost colourless. The upper halves of the epicrania have shallow and closely situated pits in small patches. The ocelli are colourless. The ventral surface of the head and mouth parts are creamy-yellow, with the bases of the maxillae being black. The pro-thorax is narrower than the meso-thorax and has a glossy, lightly chitinized shield covering the whole of the dorsal surface. The three pairs of thoracic legs are glossy, and

Fig. 1. Longitudinal section of gall showing the larva within (natural size).

Fig. 2. Gall showing the larval emergence hole (natural size).

Fig. 3. Leaf showing pupal chamber formed in nature (×2).

Fig. 4. Leaf showing construction of pupal chamber in captivity (natural size).

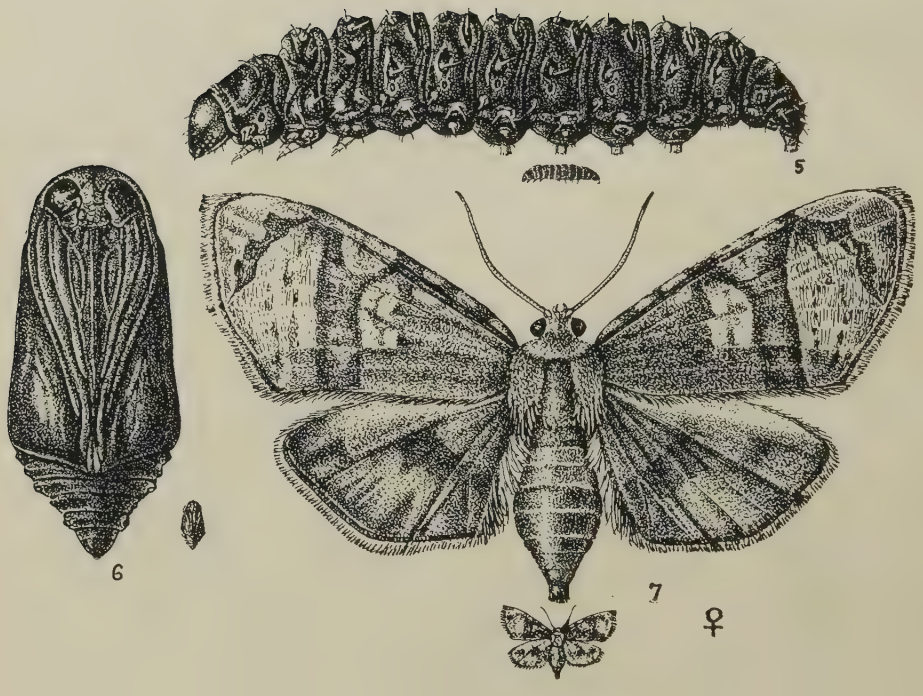

Fig. 5. Caterpillar, lateral view (×.8).

Fig. 6. Pupa, ventral view (×8).

Fig. 7. Moth (×6).

(Small figures—natural size).

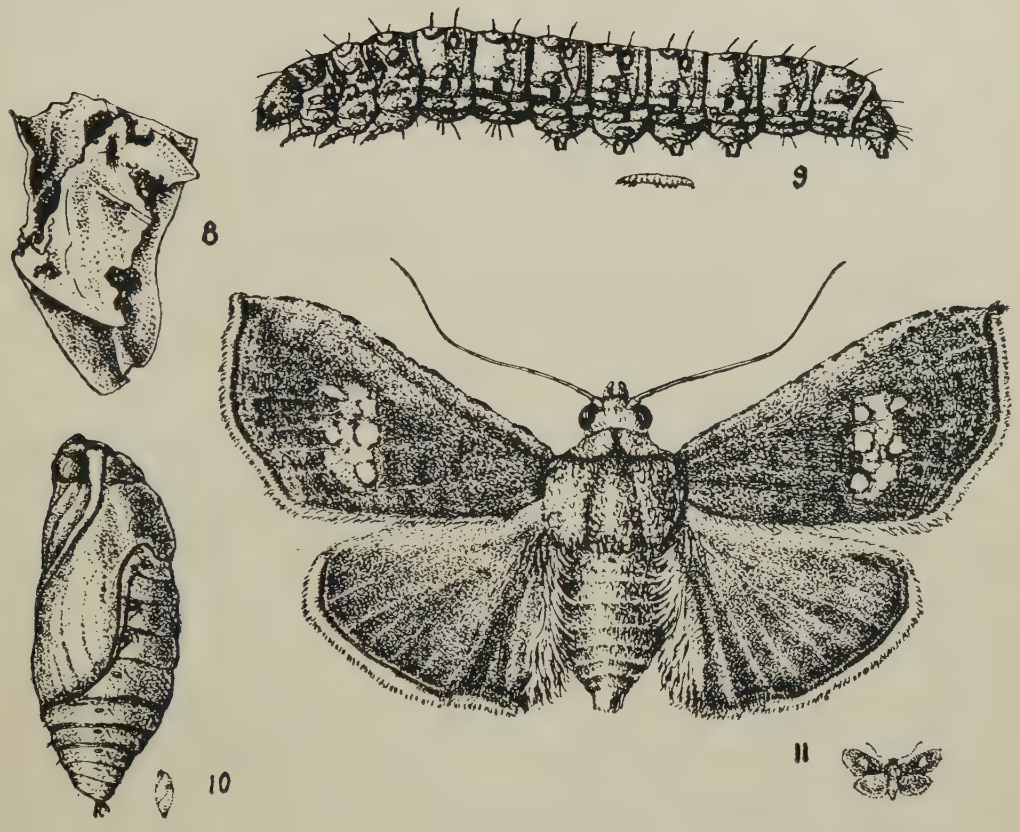

Fig. 8. Leaf-bits containing the feeding, larva within.

Fig. 9. Caterpillar (×8).

Fig. 10. Pupa (×8).

Fig. 11. Moth (×8).

(Small figures—natural size).

creamy-yellowish in colour. The tarsi and claws are brown and darker brown respectively. The colour of the rest of the thorax and abdomen is jet-black. The various body segments are distinct and have minute, fine, brownish hairs which arise singly on the dorsal surface from patches which are arranged trapezoidally on the first to eighth abdominal segments. The anterior pair of patches on each segment are nearer the mid-dorsal line and are much smaller in size than the posterior pairs which are wider apart. The tenth segment constituting the anal plate is glossy, lightly chitinized and dark sepia-brown in colour. The entire skin of the body appears to be shagreened closely. The hooklets of the prolegs are arranged in the form of a complete circle on the first four pairs, but semi-circularly on the anal claspers. The spiracles are minute, oval and black in colour and have thick rims, the first and the last pair of spiracles being larger in size than the rest.

The caterpillars form pupal chambers in the following manner (Plate XXXIV, fig. 4) :—

When full grown, the caterpillars come out of the galls and start making pupal chambers. Five leaflets are used in the preparation of each chamber. Three of these leaflets are utilized to form the base of the chamber. The basal part of these three leaflets are stuck together by means of silken threads to form the base, the remaining three-fourths are left free, sticking out like fingers. The middle portion of the chamber is formed with the other two leaflets. The leaflet of the right side of the rachis is turned into a spiral towards the left and that of the left side towards the right, the two leaflets together forming the barrel or body of the chamber. The upper end is covered by a close mesh-work of silken threads with a deposit of chewed and regurgitated leaf tissue over it. Any other chink is similarly closed up so that the chamber is well closed on all sides. The leaflets help much to give strength and safe shelter to the pupa inside and the formation of such a cocoon involves a very little secretion of silk. The caterpillars pupate within the chambers about two days after emergence from the galls. In the absence of these chambers they fail to pupate. The pupa (Plate XXXV, fig. 6) measures about 6 mm. in length and about 2·75 mm. in breadth across the fourth abdominal segment. It is beautiful red in colour. The wing cases reach the middle of the fifth abdominal segment ventrally. The visible spiracles are situated on the fourth to eighth abdominal segments ; they are elongate, oval, narrow and have light brown rims. In Pusa, the pupal period lasts from eight to ten days in the month of May and June. The moth (Plate XXXV, fig. 7) emerges through the anterior end of the pupal chamber.

Distribution of the species.—In the Pusa collection, in addition to the fourteen specimens reared from caterpillars collected at Pusa, there is one moth which was collected at Kurseong. Hampson [1896] recorded the species from the Khasis hills and Ceylon.

II. *Rhodoneura locusalis* Wlk. (Plate, XXXVI, figs. 8-11)

The egg stage is not known yet.

The caterpillars of *Rhodoneura loceusalis* Wlk. which feed on leaves and bore tender top shoots of *Loranthus longiflorus* have been collected at Pusa in November to April and then again in July and August. It is quite probable that they breed on this food plant throughout the year.

The caterpillars bind two tender leaves together and feed between them (Plate XXXVI, fig. 8) either by nibbling on the green tissue in small patches leaving the lower epidermis intact or feeding upon entire portions of the leaves. They also bore top-shoots and roll up the tender leaves, or feed on thick petiole and leaf under cover of meshes of silken threads overlaid with larval frass. The caterpillars shun light and prefer to feed under cover.

A full-grown caterpillar (Plate XXXVI, fig. 9) measures about 10·5 mm. in length and 2—2·25 mm. across the middle of the abdomen. It is cylindrical, tapering gradually in the posterior region. The head is shiny, yellowish-brown, bilobed, with its base slightly retracted within the pro-thorax. There is a small black marking laterally on each occiput at the base. The pro-thoracic shield is shiny, yellowish brown, concolorous with head, chitinized and has a faint thin colourless longitudinal stripe along the middle line ; the anterior thin transverse margin is also colourless. The three pairs of thoracic legs are colourless or creamy-yellowish, glossy, and their tarsi are yellowish-brownish. The colour of the rest of thorax and the abdomen is creamy-yellowish. Each body segment bears shiny, lightly chitinized, round or oval patches, each bearing one, two or three minute hairs. The five pairs of prolegs are short, cylindrical, glossy and colourless. The first four pairs have complete rings of brown hooklets, whereas the fifth or the anal claspers have the hooklets arranged in a semi-circular fashion.

All the nine pairs of spiracles are prominent, black, roundish-ovalish in shape and have thick black rims. The first and the last pair are larger in size than the rest. The dorsal surface of the anal segment is shiny and lightly chitinized and sepia-yellowish in colour.

Cocoon.—The caterpillar forms a roundish-ovalish cocoon well covered on all sides with larval frass, and it emits through its mouth a reddish juice which imparts a reddish tinge to the cocoon.

Pupa.—The pupa (Plate XXXVI, fig. 10) measures about 6 mm. in length and 2·25 mm. across the fourth abdominal segment. Its colour is yellowish-brown. The bases of the antennae are slightly raised or ridged and the ridges are joined by a central transverse ridge at the head. The first seven abdominal segments are distinct. The spiracles are small, oval, and darkish-brown in colour. They are situated laterally near the anterior margin of the abdominal segments. The abdomen has seven pairs of spiracles on the second to eighth segments, the pair on the last segment being closed.

The pupal period varies from nine to eighteen days depending on the season of the year (Table I).

TABLE I

Pupal period at the various times of the year

No.	Caterpillar collected on	Pupated	Emerged	Period in Days
1	13th December 1927.	19th December 1927.	3rd January 1928.	15
2	8th February 1929.	16th February 1929.	6th March 1929.	18
3	8th February 1929.	27th February 1929.	13th March 1929.	14
4	22nd March 1928.	26th March 1928.	6th April 1928.	11
5	11th July 1932.	Formed cocoon in the night of 11th July 1932. Pupated on 13th July 1932.	22nd July 1932.	9
6	3rd August 1932.	7th August 1932.	18th August 1932.	11

The moth at first sight appears to be a Geometrid but the hyaline, roundish patches on the fore-wings clearly demarcate it from that family (Plate XXXVI, fig. 11).

III. *RHODONEURA MYRSUSALIS* WLK.

The caterpillars were found feeding on *Achras sapota* (Sapotaceae) leaves on 18th September 1909 at Pusa, pupated on 19th September 1909 and the moths emerged on 26th September 1909. A caterpillar was also found rolling and feeding on leaf of *Bassia latifolia* (Sapotaceae) at Pusa early in September, 1920, the moth emerged on 11th September 1920. In the Pusa collection there is another moth of this species which was collected at Nagpur on 15th September 1908.

IV. *RHODONEURA MYRSUSALIS* WLK. VAR. *IDALIALIS*

The larva was found feeding on *Achras sapota* leaves at Pusa on 18th September 1909. The moth emerged on 26th September 1909.

V. *STRIGLINA SCITARIA* WLK.

The caterpillars were found feeding on *Dhaincha* (*Sesbania aculeata*) leaves at Coimbatore.

VI. *Dysodia ignita* Wlk.

The caterpillars were found between spun-up leaves of *Osbeckia* sp. at Shillong by Mr. Fletcher on 1st October 1916. One moth emerged from this lot on 7th March 1917. The larvae were also found on *Crataeva* (leaf ?) in Coimbatore, South India, on 3rd and 7th November 1914.

VII. *Dysodia viridatrix* Wlk.

The caterpillar was found on *Capparis diversifolia* stem (boring ?) by Y. Ramchandra Rao at Coimbatore (20th November 1916).

In conclusion, I wish to express my best thanks to Dr. Hem Singh Pruthi, the Imperial Entomologist, for kindly going through the manuscript and making many valuable suggestions.

REFERENCES

Fletcher, T. B. (1931). *Proc. Ent. Soc. London* **5**, pt. **3**, p. 68.

Hampson, G. F. (1896). *Fauna of British India, Moths*, Vol. IV, p. 483.

——— (1914). *Ann. Mag. Nat. Hist.* (**8**) **14**, p. 110.

Misra, C. S. (1919). *Proc. Third Ent. Meeting, Pusa*, Vol. II, p. 592.

Swinhoe, C. (1895). *Ann. Mag. Nat. Hist.* (**6**) **15**, p. 17.

Walker F. (1865). "List of the specimens of lepidopterous insects in the collection of the British Museum", XXXIII, p. 1111.

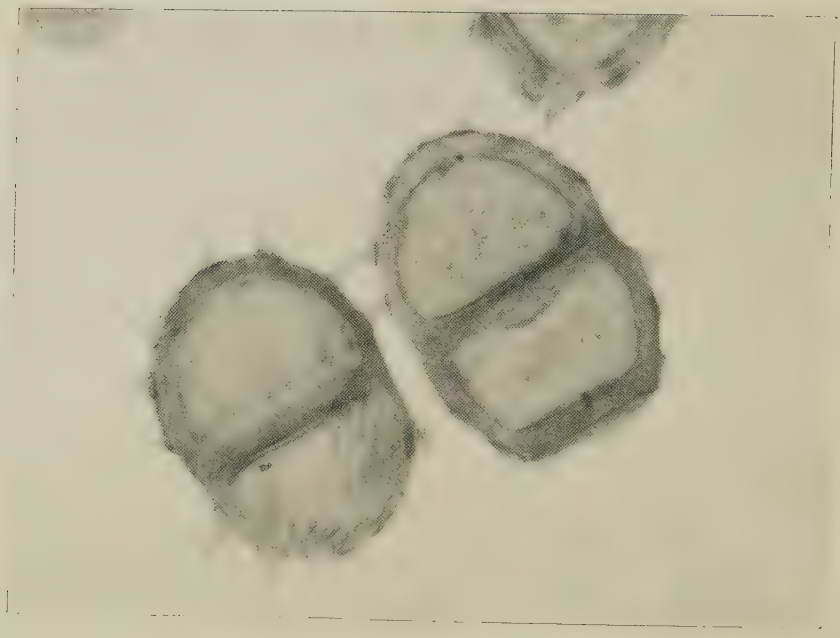

FIG. 1. Teleutospores of *P. prostii* (×900).

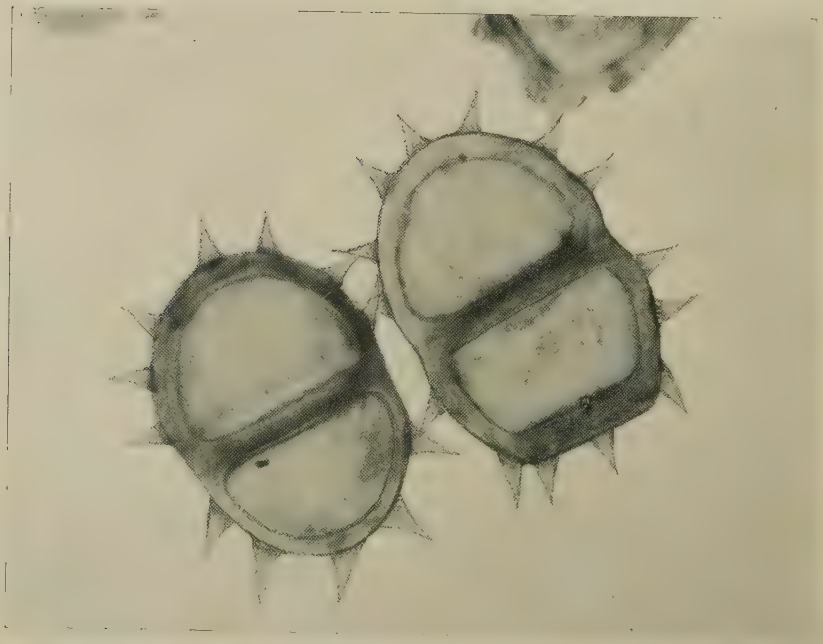

FIG. 2. Same as Fig. 1 retouched to show spines (×900).

MYCOLOGICAL NOTES

AN UNUSUAL RUST FUNGUS ON TULIP

BY

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(Received for Publication on 28th August 1935)

(With Plate XXXVII)

Among some specimens received at Pusa in May 1935 from the Agricultural Officer in Baluchistan, was a leaf of *Tulipa* sp. showing blackish sori at first covered and later bursting through longitudinal splits of the epidermis. The brown teleutospores, which were formed on both surfaces of the leaf, were borne on short pedicels and were covered with sub-hyaline spines 5-8μ in length. No spermogonia were found, but the teleutospores were unmistakably those of *Puccinia Prostii* Moug. A request for more material had to be set aside owing to the catastrophic earthquake at Quetta.

Puccinia Prostii with its very characteristic spiny teleutospores, does not appear to have been previously recorded for India. Saccardo [1888] states that it occurs on *Tulipa sylvestris* and *T. celsianae* in France and Italy. Massee [1913] gives a reference which suggests that it was recorded by him in Britain. Wilson [1914] gives a fuller description, with photographs, of the rust which he reports as doing considerable damage on *Tulipa sylvestris*. He mentions the production of spermogonia, which are not mentioned in previous descriptions.

The accompanying photomicrograph and re-touched photomicrograph (Plate XXXVII) show the characteristic structure of the spores. As regards their size, there is some variation in the literature quoted above. Saccardo gives the teleutospore size as 60-66 × 34-36μ, Massee as 54-66 × 34-40μ and Wilson as 56-62 × 17-19μ. This last measurement for width is an obvious error, as is shown by Wilson's own photographs.

Teleutospores of the Quetta specimen, measured in lacto-phenol, gave the following results :—

Mean of fifty measurements $53{\cdot}6 \times 37{\cdot}4\mu$.

Range $44\text{-}66 \times 30\text{-}46\mu$.

REFERENCES

Massee, G. (1913). 'Mildews, Rusts and Smuts'. London, 1913, p. 139.

Saccardo, P. A. (1888). *Sylloge Fungorum* **7**, 732.

Wilson, M. (1914). *Notes Roy. Bot. Garden, Edinburgh*, **38**, 219.

FIG. 1.

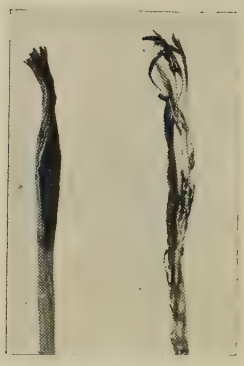

FIG. 2.

FIG. 3.

OAT LEAF INFECTION BY *USTILAGO AVENAE* (PERS) JENSEN

BY

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(Received for publication on 28th August 1935)

(With Plate XXXVIII)

The pathological effect usually produced by *U. avenae* on the oat plant is a complete destruction of the kernel and the enclosing glumes. The spores are disseminated as soon as the panicle emerges out of the boot and the central axis is thus completely exposed. This smut is rather rare in India, the more usual form being covered smut (*U. kolleri* Wille), but in the winter of 1934-1935 it appeared in Fulghum, Burt, Early Champion, Danish and Danish Island, oat varieties recommended by Reed [1927] as differentials in the determination of the physiologic races of covered smut and obtained from him.

On the variety Early Champion, Danish and Danish Island not only were the panicles affected but the upper leaves were also attacked. The sori developed on the blade of the flag leaf or on the leaf just below it; they occurred mostly on the ventral or upper side and were in the form of parallel striae. The sori were covered by the leaf tissue and the spores were released when this was ruptured. Many of the leaves became longitudinally shredded. Figures 1, 2, and 3 of Plate XXXVIII will make the above symptoms clear.

Exceptional cases of smut sori developing at unusual positions are well known. Jones [1896] has already recorded the infection of oat leaves by the loose smut and Lang [1913] has shown that he could produce the sori on the topmost leaves by checking their growth. Riehm [1914] observed a similar condition in the case of loose smut of wheat. Reed, Griffiths and Briggs [1925] found this condition to be rather prevalent in oat plants grown in the green-house, occasionally occurring in the field also. D'Almeida *et al*, quoted by Reed, Griffiths and Briggs [1925], seem to have considered the leaf-attacking form as a separate variety of smut which they have called *U. avenae* var. *foliicola*. At Pusa the condition was noted in the fields where growth of the leaves was not checked in any way.

REFERENCES

Jones, L. R. (1896). *Vt. Agric. Expt. Stn. 9th Ann. Rpt.*, 106-112.

Lang, W. (1913). *Jahresber. d. Ver. f. Ang. Bot.* **10**, 172-180.

Reed, G. M. (1927). *Mycologia* **19**, 21-28.

Reed, G. M., Griffiths, M.A. and Briggs, F. N. (1925). *U. S. Dept. Agric. Bull.* **1275**, 34-36.

Riehm. E. (1914). *Ber. d. Deutsch. Bot. Ges.* **32**, 570-573.

ABSTRACTS

Study of the evaporation of water from a soil surface with reference to the fluctuation of water-table. V. I. Vaidhianathan and Hans Raj Luthra.

(*Punjab Irrigation Research Institute Research Publication, Vol. 5, No. 3, November 1934*).

The ' Introduction ' and ' Summary ' are reproduced below :—

INTRODUCTION

During discussions of methods of cultivation to be undertaken in certain low rainfall areas in the Punjab, the question of the supply of water from a water-table to the surface arose. The conclusions arrived at by the earlier workers, regarding this question, were not definite. For example, Keen working at Rothamsted concluded that the upward capillary movement was ineffective even when the water-table is 80 cm. below the surface. In a later work, Keen mentions that water which has receded about 180 cm. is not drawn back by surface evaporation. McGee, from his investigations in the great planes of America, thought that water could rise at least 10 feet in a year and 30 to 35 feet in a favourable term of years. Hall suggested that soil moisture could rise to some 200 feet. Mitscherlisch made a calculation, which led to values of many hundreds of feet.

During certain previous investigations of the sub-soil water movement carried out in the Institute, it was observed that the water-table showed a fluctuation during each day in addition to a gradual fall in the hot season. It was thought that this fluctuation might be due to the evaporation of water from the surface during the hot portion of the day, the water from the water-table rising to the surface through the pores in the soil to replace that lost by evaporation. This would result in the lowering of the water-table. The fact that the water-table attained a maximum depth at about 13 hours supported such a suggestion. West working in Australia had observed that the sub-soil water-table showed a fluctuation depending on the atmospheric pressure. According to his conclusions when the atmospheric pressure increased, the level of the water-table went down and when the atmospheric pressure decreased, the level came up. The relation appeared to be so complete that no other factor seemed necessary to account for the fluctuation of the water-table. E. G. Bilham from his observations in a well at the Kew Observatory had also noticed that the sub-soil water-table fluctuated with the change of barometric pressure. Arrangements were made, therefore, to investigate the possible relation between the fluctuations of the water-table, evaporation, and barometric pressure.

The preliminary experiments were carried out in the Laboratory and the final ones in an area at the Lahore Cantonment. The latter area was not influenced by pumping and irrigation. The fluctuations of the water-table were therefore due only to natural causes. The month of June when the experiments were carried out was the most favourable period for the experiments, as it is the hottest and driest month in Lahore.

SUMMARY

1. The amount of water evaporating from the surface of the soil in an area near Lahore in the Punjab has been determined. It has been found that this is about $2 \cdot 7 \times 10^{-7}$ grms. per sq. cm. per second on the average for the month of June ; the temperature of the soil surface being about 66°C. during the hottest part of the day.

2. The dependence of the fluctuation of the water-table on surface evaporation and atmospheric pressure has been investigated. It has been found that while pressure has an effect on the fluctuation of the level of the water-table ; when the surface evaporation is high, the latter effect is the most predominating and the effect of pressure becomes negligible. The conclusions of the previous workers that pressure is the main factor affecting the level of the sub-soil water-table are not therefore found applicable to the conditions existing in the Punjab.

3. The moisture content of the soil from the water-table to the surface has been determined. It has been found that there is a continuity in the moisture content, though the gradient of the curve connecting the moisture content and the depth below the surface is not uniform.

4. The different results in the investigation have led to the conclusion that water is returning to the surface from a depth of 22 feet or 6·7 meters, which was the depth of the water-table in this investigation. The quantity that is being drawn up to the surface is too small for cultivation.

A soil moisture meter depending on the " Capillary pull " of the soil. With illustrations of its use in fallow land, grass orchard, and irrigated orchards. W. S. Rogers. (Horticultural Research Station, East Malling, Kent). The Journal of Agricultural Science (Cambridge), July 1935, Volume XXV, Part 3.

This paper describes a method for the continuous measurement of soil moisture which should be of very considerable use to research workers in India. The instrument was designed at the East Malling Station, has been in use there for over two years and has proved itself adaptable to a wide range of conditions. The author summarises his results in the following words :—

1. A soil moisture meter which gives direct and continuous measurement of the soil moisture content is described. The instrument consists of a special porous pot filled with water, connected by a tube to a mercury manometer. The pot is buried in the soil, whose capillary pull causes the mercury to rise. The height to which the

mercury rises depends on the amount of moisture in the soil, and also on the size of soil particles and the degree of compactness of the soil. (The last two factors remain constant for an instrument in one position).

2. To read actual moisture percentage each instrument has to be calibrated for the soil in which it is placed. Once this is done, all sampling and weighing is eliminated.

3. The range of the instrument in its present form runs from saturation to about 1·5 per cent moisture (calculated on dry weight) in sand, to about 8 per cent in light loam, and to about 21 per cent in heavy clay.

4. Within this range increases and decreases of soil moisture are recorded rapidly and consistently.

5. This type of moisture is prevented from giving absolutely precise readings of the soil moisture content owing to the fact that the moisture : pressure-deficiency curve tends to form a hysteresis loop, *i.e.*, does not follow exactly the same course for rising moisture as for falling moisture. The degree of accuracy appears to be sufficient for many purposes, however, for the variability is usually within 10 per cent.

6. Special devices are used to prevent freezing and enable the instrument to give a record over long periods without attention in the field.

7. Examples of the working of this moisture meter in the laboratory and in the field are given. Instruments placed at different depths in clean cultivated land and in grass orchards have shown the contrast between loss of water by evaporation, which hardly affects the soil moisture at 30 in. and loss by root absorption which draws on the deeper layers as well as the surface layers of the soil.

8. In an irrigated orchard the meters have satisfactorily shown the penetration of irrigation water and the drying out of the soil at various depths.

The original paper should be consulted for details. The appendix gives full particulars of the design and the method of construction and installation. Two forms of the complete instrument are now on the market.

NOTES

Standard Form of Certificate for Plant Imports into England, Scotland and Northern Ireland

It is notified for general information that His Majesty's Government in the United Kingdom have adopted the standard form of certificate given below for plant imports into England, Scotland and Northern Ireland.

CERTIFICATE

This is to certify that $\frac{\text{the living plants or plant products}}{\text{a representative sample of the living plants or plant products}}$

(*strike out the words not applicable*).

included in the consignment, of which particulars are given below were/was thoroughly examined on the (date).....by (name)..... a duly authorized official of the ..... and found to be healthy, no evidence of the presence of any injurious insect, pest, or disease(destructive to vegetation)

(destructive to agricultural or horticultural crops) having been [insert words in ( ) if required by existing legislation]

found in/on them and that the consignment (including the packing) covered by this certificate has/has not been treated in the following manner (*e.g.*, fumigated with.....or disinfected with.....) $\frac{\text{prior}}{\text{immediately subsequent}}$ to inspection.

Inspected in the field by a duly authorized inspector on.....

Not inspected

.....

(Signature).....

Official Status.....

Date .....

No. and description of packages.....

Distinguishing marks .....

Description of living plants or plant products or parts thereof.....

.....

Stated to be grown at.....

Exported by .....

Name and Address of consignee.....

Name of vessel or particulars of route.....

.....

Date of shipment.....

Port or place of entry.....

Additional Certificate(s) attached.....

LIST OF PUBLICATIONS OF THE IMPERIAL AGRICULTURAL BUREAUX (1934-35)

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